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ABSTRACT

While increasing teachers' scientific knowledge base has been identified as a challenge for teacher education (e.g., NCES, 1996), the skills used to identify a need for knowledge and the skills necessary to search for that knowledge have been less discussed. Yet, the ability to learn for oneself is really the goal of lifelong teacher education. In this paper, four class periods of video data from a problem-based educational psychology curse were examined and an eight-minute segment was chosen to analyze in depth. The preservice science teachers grapple with science concepts of electricity and atomic structure as they analyze a video case of a physics classroom and devise ways to redesign instruction in order to enhance students' learning. Three analysis were undertaken: 1) categorizing the scientific discourse to determine how student teachers identify a need for knowledge and how they solve it; 2) analyzing the resources used to build understanding, including how student teachers present themselves as resources, which outside resources are used and why, and the status of those resources in the community; and 3) investigating learning-what did student teachers seem to understand based on the current data sources and how does this compare to an expert view of electricity? The results presented here indicate our current understanding of many rich sources of information, rather than a final analysis. Our discourse analysis of the video segment showed the student teachers identified a need for knowledge in the form of a direct question, or two types of inquiring statements. Most often, they attempted to answer the science question among themselves. The science mentor, World Wide Web, and facilitator were also helpful in building new knowledge. Student teachers made few reflective remarks during problem solving. They engaged in extended scientific reasoning during the video segment, constructed concepts related to charge imbalances, and generated difficult questions, according to science experts. Changes in the role of the participants, facilitator, and other resources are recommended. Coded transcript, transcript conventions, excerpt from final paper, and page of interactions with mentOr are appended. (Contains 44 references.) (Author/DDR)

# "But Electricity Isn't Static": Science Discussion, Identification of Learning Issues, and Use of Resources in a Problem-Based Learning Education Course

Marcel A. Siegel
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Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (St. Louis, MO, March 25-28, 2001)

# "But Electricity Isn't Static:" Science Discussion, Identification of Learning Issues, and Use of Resources in a Problem-Based Learning Education Course

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Paper presented at the annual meeting of the National Association for Research in Science Teaching (2001) St. Louis, MO.

**Abstract**
While increasing teachers' scientific knowledge base has been identified as a challenge for teacher education (e.g., NCES, 1996), the skills used to identify a need for knowledge and the skills necessary to search for that knowledge have been less discussed. Yet, the ability to learn for oneself is really the goal of lifelong teacher education. In this paper, four class periods of video data from a problem-based educational psychology course were examined and an eight-minute segment was chosen to analyze in depth. The preservice science teachers grapple with science concepts of electricity and atomic structure as they analyze a video case of a physics classroom and devise ways to redesign instruction in order to enhance students' learning. Three analyses were undertaken: 1) categorizing the scientific discourse to determine how student teachers identify a need for knowledge and how they solve it; 2) analyzing the resources used to build understanding, including how student teachers present themselves as resources, which outside resources are used and why, and the status of those resources in the community; and 3) investigating learning--what did student teachers seem to understand based on the current data sources and how does this compare to an expert view of electricity? The results presented here indicate our current understanding of many rich sources of information, rather than a final analysis. Our discourse analysis of the video segment showed that student teachers identified a need for knowledge in the form of a direct question, or two types of inquiring statements. Most often, they attempted to answer the science question among themselves. The science mentor, World Wide Web, and facilitator were also helpful in building new knowledge. Student teachers made few reflective remarks during problem solving. They engaged in extended scientific reasoning during the video segment, constructed concepts related to charge imbalances, and generated difficult questions, according to science experts. Changes in the role of the participants, facilitator, and other resources are recommended.

**Multiple Paper Set: Getting a Charge out of Static Electricity: Interaction Video Analyses of Preservice Science Teachers during Problem-Based Learning**

This article is part of a multiple paper set focusing on a video analysis of four class periods during problem-based learning in a teacher education class. We describe ways in which student teachers constitute their scientific knowledge about electricity and the atom by examining the participants' role in their construction of knowledge and the resources they employ. The related papers investigate the group's construction of knowledge through argument and discourse (Steinkuehler), and the facilitator's role in student teachers' knowledge construction (Derry, Seymour, Feltovich, & Fassnacht).

**Outline**



## Background

Much research has been accomplished on selected areas of teacher knowledge, including beliefs about teaching (for review, see Calderhead, 1996), the teaching process (for review, see Borko & Putnam, 1996), and frameworks for representing teachers' knowledge (Elbaz, 1983; Clark & Peterson, 1986; Shulman, 1987). However, in our view, much previous work has defined teacher knowledge too narrowly (see Sherin, Sherin & Madanes, 1996 and Schoenfeld, 1998 for alternative conceptions). For example, Shulman suggests a scientific knowledge base for teachers that includes subject matter content, pedagogical content, general pedagogy, and an understanding of learners, educational aims, and curriculum (Shulman, 1987). Subject matter knowledge is composed of

knowing how the basic concepts of a discipline are organized and knowing ways that competing claims can be critiqued. However, metacognitive knowledge of thinking skills—for instance, how to apply reasoning skills to problem solving and how to think about one's own thinking processes—is not included (see Zohar, 1999 for an exception). In addition, teacher educators often do not designate the ability to talk about science in a collaborative, scientific manner as a goal of professional development. Thus, from our perspective, attention to the issues of metacognition and sociocultural discourse has historically been lacking in studies of teacher learning. In this study, we examine preservice discourse to characterize ways that teachers rely on their peers, assess the state of their understanding, seek out new resources, and construct new science knowledge for themselves.

**Basis for Our New Course**

The goal of our course is to help preservice teachers engage in scientific discourse about learning and instruction and be able to flexibly apply cognitive ideas to the design and evaluation of classroom environments. We have combined three instructional approaches in the design of the course (see S. [removed for review] 2000). One of these is problem-based learning (PBL) (Barrows, 1988) – engaging teachers in collaborative problem solving in a way that requires them to use theory as a tool for addressing real instructional problems.

We have developed online teacher education materials (the *Knowledge Web*, http://www.wcer.wisc.edu/step), including video-based cases and problems depicting real instructional scenarios, for our Educational Psychology course at the University of Wisconsin-Madison. Preservice teachers

(1) study video cases of actual instruction and a related problem to be solved;
(2) formulate hypotheses about cases that will prompt investigation into the content of the learning sciences and disciplinary subject matter;
(3) use the *Knowledge Web* and related supports, such as an online science mentor, to guide investigations into case-relevant theory and research; and
(4) develop instructional solutions based on their research.

In order to help future teachers become lifelong learners, they require certain skills, such as how to seek out novel resources, to become metacognitively aware of their state of knowledge, and to collaboratively discuss instruction using scientific discourse. Students have an opportunity to practice these skills during our course.

**Learning Resources in the Problem-based Learning (PBL) Student teacher Community**

The National Board for Professional Teaching Standards (NBPTS) has stated that teachers need to be able to seek the advice of others and draw on education research and scholarship to improve their practice (Coble & Koballa, 1996). Several resources for increasing science knowledge about the physics case were available to the preservice teachers via the course. These included online

accessibility of a *mentor*, the *facilitator* in the PBL group, other *preservice teachers* in the PBL group, science resources available via the Knowledge Web and the *World Wide Web*.

Various standards boards, such as the National Research Council, recommend that scientists make contributions to science education (NRC, 1996a). The American Association for the Advancement of Science's Project 2061 has suggested that first-hand experiences in schools, teaching and mentoring experiences, and fieldwork with scientists must come early in the teacher education program (AAAS, 2000). For our course, each science *mentor* was introduced to the complicated class beforehand during a three-hour meeting in which the mentor engaged in PBL to solve a similar video case-problem.

The mentors' objectives in interacting with the students were described as:

- Improve disciplinary content knowledge
- Enhance the preservice teachers' confidence with the subject matter
- Portray current practices in their field
- Push preservice teachers! The goal is in-depth, non-trivial, authentic knowledge of the discipline.
- Suggest resources (literature, people, labs, etc.)

In addition to the mentors, the *facilitator* for each PBL group provided disciplinary knowledge support. In the science group, the tutor did not have a science background, so her role was limited to helping students find resources and critique resources. Over an hour of class time during the eight hours of the problem were spent doing this.

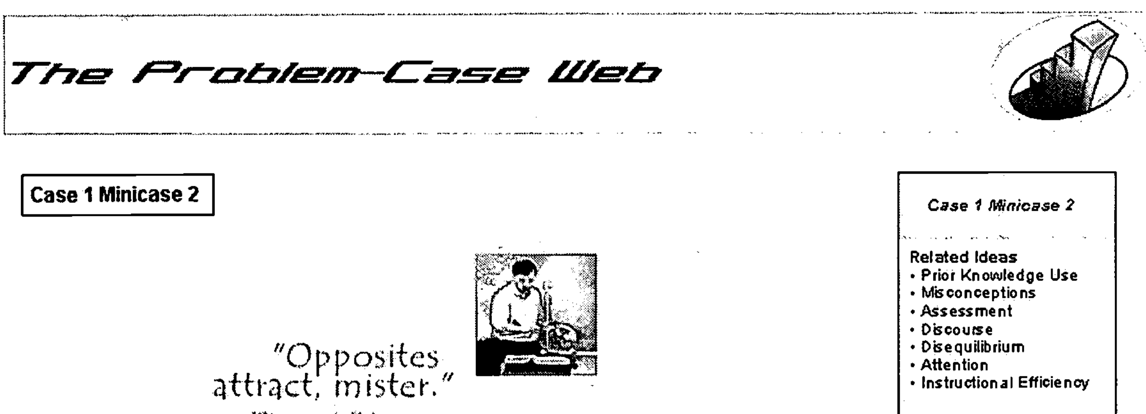


**Figure 1. Knowledge Web Page**

Also, the *preservice teachers* in the PBL group were from different science backgrounds and had varied amounts of expertise in physical science. They served as disciplinary resources for each other. As part of the PBL philosophy, they were responsible for each other's learning. Another aspect of PBL related to the use of science resources is to identify "learning issues" or things one needs to know in order to solve the problem. After identifying these, the group assigns one or more people to research the topic outside of class. The facilitator suggests

resources or places to look for information, and the student teachers report on their findings at the following week's PBL meeting.

Finally, science resources were available from the instructional *Knowledge Web* site as well. The site contained one page of content information about science education, several pages of content information about static electricity, and several Web links and text references for students to explore. Figure 1 shows a page linked to a segment of the video case used in this study and links to other pages. In addition, the preservice teachers used the internet to look for information about static electricity.

**Research Questions**
The purpose of this study was to describe ways in which student teachers became aware of a need for additional science knowledge while solving the redesign problem and to examine the types of resources employed in seeking answers. Three analyses were undertaken:

1) categorizing the **scientific discourse** during a knowledge-seeking episode about static electricity to determine how student teachers identify a need for knowledge and how they solve it.

2) analyzing the **resources** used to build understanding, including how student teachers present themselves as resources, which outside resources are used and why, and the status of those resources in the community;

3) investigating **learning**--what did student teachers seem to understand based on the current data sources and how does this compare to an expert view of electricity?

**Method**
***Participants:*** The participants for this study were undergraduates in a teacher certification program enrolled in Educational Psychology 301 during the spring of 2000. Eighteen participants were selected from those who requested to be in the study. Participants were chosen first by subject area so that there would be an even distribution of subjects from different disciplines, and then were chosen randomly. Participants were paid by the hour at a university rate for up to ten hours of tasks that extended beyond regular classroom activities. In this study, we focus on five of the science students from one problem-based learning group.

***Mentors:*** For our course, mentors were recruited from various departments at the University of Wisconsin and committed to spend a few hours per month talking online with the student teachers on a voluntary basis. The science mentor for the group we studied was a graduate student in physical science, who has been a teaching assistant in the physics department for seven semesters. Mentors interacted with student teachers online using asynchronous discussion software called First Class. Transcripts of the interactions were analyzed as a supplementary source of information.

***Videotapes versus Video cases:*** Because there could be confusion about student teachers using videotapes to think about instruction and the researchers watching videotapes of student teachers, these will be further defined. In the remainder of the paper, the term **video case** will be used to refer only to the cases

of teaching that the preservice teachers watch , and video or **videotape** will be used to refer to the videorecord of the preservice teachers' PBL process that is analyzed by the researchers.

*Video case:* Student teachers viewed a video case from STEP's Web site showing a traditional-style teacher leading two classes on static electricity and atomic structure. A still shot from the video is shown in Figure 2.

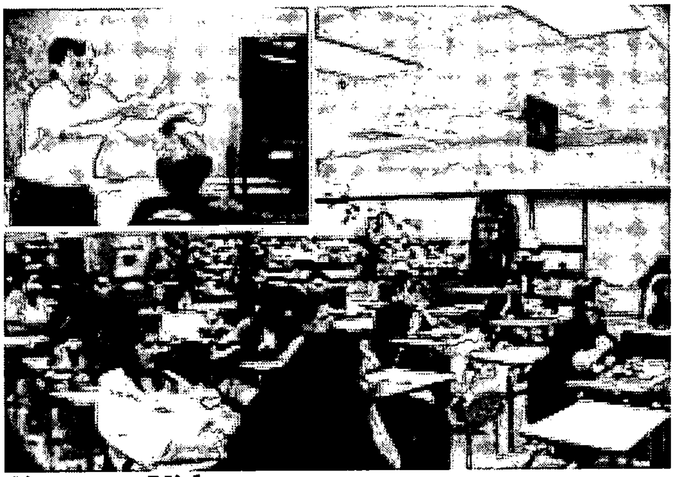

**Figure 2. Video case**
"Mr. Johnson" is a science teacher at a large urban high school. It is the middle of May. He is beginning a unit on static electricity, which he plans to complete in two days.

*Problem:* The problem that student teachers were asked to solve was basically to redesign instruction to improve student learning by analyzing the beneficial and deficient aspects of the class and recommending changes. The group had four weeks to discuss the problem during classtime and to complete research outside of class. By the fifth week, the analysis was written up in a group paper that included justification of ideas using cognitive theory. More details from the problem are shown in Figure 3.

**Problem 1: Redesigning the High School Classroom**

This Problem is compatible with:
**Case 1: The Classroom Gets a Charge (Static Electricity)**

**I. Background**
Teachers from secondary schools in your region recently attended a summer institute to learn current scientific knowledge about student learning and development. The institute created much enthusiasm and led to the formation of a distributed teacher's professional development community, a web-based group in which teachers meet on-line to support one another and share ideas as they design instructional projects using ideas from the summer institute.

Blair Johnson, a popular and experienced teacher, has just presented a problem for the community to consider:

## II. Instructional Design Problem

An instructional unit that is required by state standards and that Blair has been teaching for many years is not working to Blair's satisfaction. Although some students seem to enjoy the unit, many do not become involved and few if any students appear to gain a truly useful understanding of the concepts being taught. Blair says budgetary and time constraints make it necessary to reuse many of instructional materials (textbook, supplies, equipment, etc.) already available for the unit. Also, the unit must be taught in the same number of days.

Yet, Blair thinks that ideas from the summer institute could help greatly improve the lesson. Fortunately, Blair is web-savvy and able to post documentation such as instructional materials and other information about the unit on a web site for convenient access by the workgroup. Blair also made a video of the instruction that can be downloaded and viewed by the workgroup and other members of the community.

## III. STEPs in Student Task

(Note: In order to easily refer back to this problem, you should either print out this page or keep it open by opening another browser.)

1.This problem is a collaborative problem solving activity designed for use with STEP Web materials. It is assumed that users of this problem are working in small discussion groups with a designated leader or tutor. **The general goal for your group will be to function as Blair's workgroup - to analyze Blair's unit from a learning sciences perspective and propose a redesign strategy.**

2.Locate the case you will be using with this problem. (All compatible cases are listed as "Children" under Related Ideas.) Three types of materials will be associated with the case:

***Case description** (including video) of Blair's instruction

***Conceptual curriculum** - links to relevant scientific information about student learning and development

***Inquiry materials** - further information and details about Blair's classroom

3.Before meeting with your group, carefully examine the case description, including the video. Conduct a preliminary case analysis by exploring the conceptual curriculum (see "Related Ideas" on the case page).

4.Meet with your group to view and discuss the case. The web is designed to support increasingly in-depth problem analysis, which your group will need to do. You will not have time to study all the relevant issues in depth, so you will need to decide as a group what psychological concepts should be explored in depth.

***FirstClass (Asynchronous Discussion Tool)**

5.Distribute group tasks to get the job done within time limits and provide maximum participation from all group members. Your group leader will have some helpful hints.

6.As your group works, it may desire additional information about Blair's case. This can be found in the Inquiry Materials associated with your case.

**Figure 3. Problem-Based Learning Assignment**

*Making the Videotapes of the PBL Group:* The science group that was videotaped for this study worked on the problem for 8 hours over 4 weeks. The tapes show the 5-person group plus facilitator engaging in PBL during 4 class periods of about 2 hours each. Tape was shot from a camera that was usually stationary and an operator occasionally zoomed in on student work or an individual speaking.

While videotape offers more interaction, expression and details to observe than notes or audiotape, it is still limited in that the whole context cannot be present on the screen, and it only offers a snapshot of time. The camera also has a potential effect on the way students and teachers act (Stigler, Gallimore & Hiebert, 2000). We attempted to overcome these limitations of using video by having observers visit the classroom to note the overall context and take periodic field notes.

*Preliminary Approach to Video: Interaction Analysis:* Having researchers analyze a tape from different perspectives can be especially useful. It has been recommended to analyze classroom video data by a team of observers with diverse and specialized skills (Stigler et al., 2000). In this study, the five researchers who participated in group analysis sessions were: 1) teacher educator and educational psychologist with experience as an English teacher, 2) science educator with a biology and cognitive science background,
3) educational psychology graduate student with a focus on argumentation and social interaction, 4) educational psychology graduate student with a focus on cognition and technology, and 5) a sociology graduate student with a focus on conversation analysis.

For the three papers in the multiple set, we used *interaction analysis* as a starting point for how to structure the study (and Derry et al. used it further). Interaction analysis is an interdisciplinary approach for investigating the interaction of people with each other and with their environment (Jordan & Henderson, 1995). The goal is to identify regularities in the ways in which people utilize the resources of the complex social and material world and to see how social order is attained by how people make sense of each other's actions and words (Jordan & Henderson, 1995).

For this paper, the purposes of the interaction analysis sessions were to identify a relevant video segment(s) in which the preservice teachers identified a need for additional science knowledge to analyze further and to supplement that further analysis. The first author participated in three interaction analysis sessions that were audiotaped. Multiple events in which students showed or identified a need for additional scientific knowledge were identified, and these took place during the student teachers' first PBL session. The segment we therefore analyzed further was 8 minutes and 23 seconds out of Day 1 (7:03-15:23). We also

intersperse quotes from the interaction analysis sessions to supplement our discussion of the chosen segment.

*Discourse Analysis Approach:* The purpose of the video analysis for this study was to categorize ways in which students became aware of a need for additional science knowledge while solving the redesign problem. The video was examined, roughly transcribed, summarized, and then transcribed in detail. The transcript is shown in Appendix 1, and the key for the notation system (Atkinson & Heritage, 1984) is shown in Appendix 2. Codes were developed for the different types of utterances by summarizing and re-categorizing the utterances. The purpose was to distinguish between 1) requests or statements of a need for more information, 2) answers or comments, and 3) reflective or metacognitive statements about what is understood. The notation system was developed by adapting prior narrative analyses of questioning, in particular, Saha's (1984) taxonomy of forms of English questions. (The coding scheme developed is described in section 1 and summarized in Table 1.)

*Supplemental Data Sources:* Four other sources of information supplemented the video analyses. Transcripts of the online interaction between students and science mentors were examined. Field notes during the PBL sessions were reviewed, and the paper drafts and final paper describing the problem solution were studied. Also, pre- and post-interviews with the student teachers were conducted and transcribed by the second author. Finally, science experts were informally interviewed to provide information about static electricity. This information helped us evaluate the accuracy and depth of the student teachers' ideas. The expert answers are cited anonymously as "personal communications." Relevant quotes from these sources will be included in the analysis to follow.

*Preliminary Work:* The analyses described here are part of an ongoing study involving multiple, contextual, rich data sources and should be considered indicative of our current state of understanding, rather than a final analysis.

**Introduction to the Video of Preservice Teachers' PBL**

The five preservice teachers and facilitator partaking in PBL are named (using aliases) and pictured in their positions about the room in Appendix 1. In the video segment we investigated, it is the first day of a new problem, and the first time the group works with this facilitator. The student teachers are to discuss the video case of a unit on static electricity and construct ways to redesign instruction to enhance student learning. Recall that we chose this particular segment through interaction analysis, because they were talking about science, not just instruction. In the segment, they begin discussing the teacher's (in the video case) use of models related to static electricity. They go on to ask questions about how static electricity works. They focus on one of the demonstrations shown in the video case, during which the video-case teacher rubs a piece of fur along a rod to create static electricity. This demonstration becomes the topic of the next 8 minutes.

## Results
## Section 1: Scientific Discourse

**Characterization of Discourse**

When a student in the PBL group runs into a scientific idea he does not fully understand, how is this made public through talk, and what happens next? The talk was categorized based on the purpose of the utterance (Table 1). Different types of questions (Q), questioning statements (S), answers (A), and reflective talk about understanding (U) were designated for student talk. If the facilitator spoke, a T was added before the code; for example, "Tq" indicates a question from the facilitator.

We defined questions (Q) as talk with a rising intonation, an inverted word order (e.g., did you…?), a tag (e.g., isn't it?), or an embedded question (e.g., I wonder if…) (see Saha, 1984). We further differentiated types of questions by their apparent purpose, such as to clarify a previous statement, or to find out about science. Statements without a rising intonation, but that served the purpose of a question by showing a need for science knowledge and being answered, were defined as "S."

Table 1
*Discourse Categories*

| Forms of Discourse | Code Abbre-viations | Examples (quotes or paraphrases from transcript) |
|---|---|---|
| **Questions (Q)** Utterances with a rising intonation | Q | |
| Clarification (c) | Qc | What? |
| Challenge to previous statement (ch) | Qch | Did you explain it right? |
| About the process (p) | Qp | Should I do this now? |
| About science (s) | Qs | What does static mean? |
| **Questioning Statement** Statement with explicit questioning purposes | | |
| Statement that shows a lack of understanding. Followed by an answer. | S | That's the one thing about- they're not just floating around. |
| **Answers** Statements or comments | A | |
| Agreement (a) | Aa | Yeah |
| Deflate (d) | Ad | This isn't my background |
| Puff (p) | Ap | I have the background, but I'm not |

| | | |
|---|---|---|
| | | telling |
| About the process (pro) | Apro | Write that down. |
| About science (s) | As | This is just the transfer of electrons. |
| **Understandings** Metacognitive comments about the state of understanding | U | |
| Understanding is made public by **h**ypothesizing (h) | Uh | What I'm picturing is... |
| Comment about understanding by saying, **no** I don't get this particular aspect (n) | Un | Okay that's the part that I don't understand |
| Understanding is shown about what the problem at hand is, or **p**lanning for what is needed to do next conceptually for the **p**roblem (p) | Up | So this has nothing to do with this |
| Comment about understanding by saying, yes that makes sense (y) | Uy | Makes sense |

*Note.* Codes indicate that a student teacher is speaking. To show that the facilitator is speaking, a T is added before the code, for instance "Tup".

Answers were separated into scientific statements (As) or comments about the process they were involved in (Apro). Short, confirming statements, such as "yes" were coded as agreements (Aa), regardless of the topic that was referenced. Two other types of answers did not fall into the other categories. These utterances were not on the topics of science or the problem process, but instead only involved the speaker herself. One was a Puff (Ap), or statement that inflated the image of the speaker. Puffs were seen as the opposite of deflating remarks (Ad). De-puffs were similar to "hedges" coded by other researchers, except that for us, deflating remarks were not necessarily used to change the topic of conversation. Hedges have been defined as: "Any claim regarding self may be made with belittling modesty, with strong qualifications, or with a note of seriousness; by hedging in these ways he will have prepared a self for himself that will not discredit exposure, personal failure" (Goffman, 1999).

Comments about understanding were categorized depending on whether they related to a hypothesis being made (Uh), the problem itself (Up), or a direct claim of "yes I understand" (Uy), or "no, I don't understand that" (Un).

After coding the entire segment, we identified student teachers' "cries for knowledge." In discourse analysis, Fairclough (1999) argues "one cannot properly analyze content without simultaneously analyzing form, because contents are always necessarily realized in forms, and different contents entail different forms and vice versa. In brief, form is a part of content." With this argument in mind, the authors used both the form and content of each utterance as a marker to identify when the need for knowledge occurs. To be considered a "cry for knowledge" the content had to be about science and somehow related to static electricity, and the form could be either a question, statement, or reflective statement. The codes that represent a need for knowledge were: a direct question about science (Qs), a less direct statement (S) that was followed by an answer about science, or a direct comment about what is unknown (Un).

Which forms of talk immediately follow these science questions? Answers about science followed questions 39% of the time (out of 13 Qs). The remaining responses were agreements (2 Aa), de-puffs (2 Ad), clarification question (1 Qc), inquiring statement (1 S), process answer (1 Apro), and puff (1 Ap). Interestingly, a science question was never immediately followed by another science question, such as 'Do the electrons completely transfer?' 'Why do they transfer?.' However, the discussion below will explain how several questions about science developed together within a short period. Questions about science that were formed as statements (S) were followed by answers about science half the time (out of 8 S). The other responses were: one science question (Qs), one inquiring statement (S), and two agreements (Aa). The third type of "cry for science," was a reflective statement (Un) that was followed by a clarification question.

Also, answers about science were most often immediately followed by another answer about science (14 out of 49 times).

The total numbers of types of statements used during the 8:23 minute clip that contained 188 turns of talk (133 turns were coded unambiguously) are shown in Table 2. The most common type of utterance was an answer about science (As), while the next most common was an agreement (Aa), a question about science (Qs), and then a comment about the process of problem solving by the teacher (Tapro).

Table 2
*Number of Categorized Utterances*

| Utterance | Number Occurred |
|---|---|
| Qc | 2 |
| Qch | 2 |
| Qp | 2 |
| Qs | 13 |
| S | 8 |
| Aa | 31 |

| | |
|---|---|
| Ad | 2 |
| Ap | 4 |
| Åpro | 2 |
| As | 49 |
| Uh | 3 |
| Un | 1 |
| Uy | 2 |
| Tapro | 11 |
| Tqc | 1 |
| Tup | 3 |
| Ts | 0 |
| TOTAL | 136 |

The most common form of speech--comparing the broader categories of answers, questions, etc.--from student teachers was an answer (A). The reflective statements were much less common, with a total of 6 (U) out of 136 coded statements.

Next, we will discuss the five science uncertainties that arose during the students' discussion about static electricity (see Table 3). The origin, discussion, and solution of these questions will be described for the main questions that were discussed the most during the clip. The other question, by Cindy at 8:18, is included in the course of describing the first question. How the segment ended will be described after that, and then the group's solution to the problem in the final paper will be highlighted. The accuracy of the solutions to the questions will be further evaluated in section 3.

Table 3
*List of student teachers' science questions during PBL discussion.*

| Time Speaker | Discourse Code | Uncertainties about Science |
|---|---|---|
| 7:39 LOU | S & Un | =I don't know why like cat hair and, plastic work the best. |
| 8:18 CINDY | Qs | But >[DON'T metals always accept electrons?< |
| 8:31 PAULA<br>AND AGAIN AT<br>10:17 PAULA<br>11:20 PAULA<br>11:56 PAULA | Qs | Where are they [the electrons] coming from? |
| 8:32 PAULA<br>AND AGAIN AT<br>11:26+PAULA | S | That's the one thing about- they're not just floating around |
| 8:40 PAULA | Qs | But, aren't you going to be changing the chemical composition...? |
| 10:27 PAULA<br><br>AND 13:09 | | And why doesn't it change the chemical composition if you're taking electrons away and why (doesn't) it all of a sudden want to bond |

| | |
|---|---|
| AND 13:53<br>PAULA | with something? |

**Science Questions**
*"I don't know why like cat hair and, plastic work the best." (7:39)*

*Origin*

This question originates while Dean is speaking at 7:25, and the facilitator, Jenna, basically asks Lou to speak by commenting on Lou's expression (7:27). Lou then asks why hair and plastic make the best materials for a static electricity demonstration (7:29-7:39. Dean immediately replies that he wonders the same thing (7:43); Paula says (Ad, 7:45) she used to know that. Then, they discuss the relevance of the question. Lou comments (Up, 7:48) that his question isn't really about the problem at hand. Jenna denies this (Tup, 7:50) and references student thinking.

(7:27) JENNA: ((to LOU)) You look like you ( )
(7:29) LOU: Ah no. Ah? (.) The one thing I was wondering when people do this is why is there things °xxxxxx° >[I] don't know why.<=
(7:38) DEAN: [Yeah.]
(7:39) LOU: =I don't know why like cat hair and, plastic (1) work the best.
(7:43) DEAN: Yeah I wonder that, myself (Lou).
(7:45) PAULA: (I was) explained that once but don't ask me to repeat it. ((PAULA chuckles))
(7:48) LOU: ((to JENNA)) So this has nothing to do with this so. ((LOU laughs))
(7:50) JENNA: Oh I think it could. I think it could because it may have been a question, that the ↑students might have that (the students can) address.

*Discussion*

The facilitator, Jenna, adds that all ideas are appreciated during this brainstorming part of the discussion (8:04). Jenna's comment is followed by two more science questions, first by Cindy at 8:18 and then by Paula at 8:31. At 8:47 (see below), Jenna tries to pull the conversation together by saying 'we need to write down these ideas.' As Jenna tries to form the question, Jenna asks Lou (Tapro, 8:55) to finish phrasing it. Lou states the question for the group as perhaps a more general statement of *Cindy's* question, saying, "Ah:::, why >I don't know.< Why different materials [accept or donate] electrons" (Up, 9:08). Dean then follows with another Up (9:12), stating what he wants to know about insulators and conductors.

(8:47) JENNA: = I think we have a couple of things, going on here, that we need to (help). That we need [to slow down and maybe EVEN if we can write down too, the learning issues.=

(8:50) CINDY: [((reaches for PAULA'S hand)) °(Wa:tch)° ((they both raise their hands and then laugh))

(8:55) JENNA: We need to:, ah, make sure that we get down, that, one possible thing we want to change is to explain, (.) ah why (.) different materials=

(9:04) LOU: Um.

(9:05) JENNA: =accept, (.) different kinds- ((to LOU)) You say it.

(9:08) LOU: Ah:::, why >I don't know.< Why different materials [accept or donate] electrons.

(9:12) DEAN: [x. Yeah,] (.) electrons. And ah: we also, wanted, (2) I think we need ta:, we need to explain more about, conductors versus insulators because he sort of talked about it, but for the thirty seconds he did, he then expected them to understand (.) exactly why charges would line up on, different sides of something and, that's not really intuitively obvious unless you REALLY understand what a conductor means. It means that electrons are free to, ((raises hands with palms downward)) float around the surface.

(9:43) JENNA: So we need to handle insulators and conductors, (.) better.

*Solution*

Interestingly, the science answer to Dean's question would also answer Lou's original question: hair and plastic readily create static electricity because they are insulators. Conductors do not show static electricity (charge imbalance) because the electrons move so readily the object can't "hold" a charge (the imbalanced charge spreads out). Later, at 13:01, Lou returns to the terms "cat hair and the stick" while he is answering Paula's question. This continues for a few turns. Towards the end of the clip, Dean mentions insulator and conductor issues again at 14:36 and wants to split up the research on scientific questions with Lou at 15:13.

Thus, Lou's question about why fur and plastic work is not answered during this discussion, nor is it brought up in later PBL sessions, online, or in the final paper. However, Dean's comments during the clip address Lou's concern. We see no evidence from the videotape that the student teachers realize that Dean's comments are related to Lou's science question. The question of why insulators work well for creating static electricity is not solved publicly by the group, although perhaps Dean has some inkling of the answer.

***"Where are they coming from?"[the electrons that transfer] (8:31)***

*Discussion (Origin described above)*

Paula asks this question at 8:31 and it becomes the jumping off point for three more questions to arise. Paula also wants to know if there are electrons just floating around (8:32). Dean says no (8:35), and at 8:40 Paula brings up new questions. When Jenna tries to summarize (8:55), Lou (9:08) and Dean (9:12) do not include Paula's question in the summary, and she says to Jenna (10:08, below), "I was asking a science question, is that okay?" Paula then asks where the electrons come from that transfer in static electricity (10:17). After discussing

if it is legitimate to the problem, Jenna confirms (10:10), and then Paula adds to her question (10:27).

(9:52) JENNA: [Before we go] (1) further, write write down what
you're thinking about. >And before we go further let's put
down the learning issues because I think that's something there
are things that we need to KNOW that you're saying we don't
know that we can ask our mentor.< So, what are those things
so that she can write up our learning issues. ((to PAULA)) You
were asking a question and I was thinking so I don't know
(what it was)
(10:08) PAULA: I was asking a science question (is that okay?)
(10:10) JENNA: A science question is valuable if it pertains to this.
If if it's something we think that they need to- that the kids
might be wondering about too that.
(10:17) PAULA: Where do the electrons come from that transfer.
(2) ((DEAN raises his hand and then puts it down and tightens
his lips ))
(10:21) LOU: You can answer it.
(10:22) JENNA: ↑Yeah you can answer [it.]
(10:23) DEAN: [Oh.] I thought we were just writing down the
learning issues. Ahm:?
(10:27) PAULA: And why doesn't it change the chemical
composition if you're taking electrons away and why (doesn't)
it all of a sudden want to bond with something.
(10:33) LOU: (Oh) I can answer that part.
(10:35) PAULA: [(There's two questions in there.)]
(10:35) DEAN: [Well between Lou and I!]
(.)
(10:37) (PAULA): Hmph.

After a challenge from Bo, " Did you explain it right? Are you really just transferring electrons or are you just (moving them around?)" (10:47), they decide that electrons do get transferred, but they do not reach a conclusion about where they are coming from. Later at 11:06, Paula starts to answer her own question by diagramming the loss of electrons from the hair. Paula clarifies her question and adds again, 'are there free floating electrons?' (11:26+). Then the question evolves (for the second time—first time: 10:27) into why the chemical composition of the substance doesn't change if electrons are removed and is the electrochemical potential and bonding behavior of the substance changed (e.g., 12:02, 13:42, 14:20).

*Solution*

As the question gets more difficult, Dean realizes he can't answer the question and covers his face with his hands at 12:06. Paula begins to draw the scenario at 12:21 and they construct an answer to her original question.

(12:21) PAULA: uh. ((She climbs out of chair and goes to board and
draws)) What I'm picturing is here's an atom and here's an

[atom and here's all the electrons] (are swarming around) and all of a sudden I just took this one.

(12:24) DEAN: [Yeah, ((nodding)) (.) I real- I realize what you're saying.]

(.)

(12:29) PAULA: And now, it's gonna, want to bond more with xxx ((sound is warped)) Let's take another one from that too. Now it's going to want to bond differently.

(12:36) DEAN: Well not necessarily. Um::, (1) It's not necessarily going to make it bond with something that's around, but it will change it's behavior chemically. >But it's not necessarily going to up and bond with something just because you took an electron away.< (1) Um::.

(12:49) LOU: It's going to lose the electrons, (1) but (1) I ↑think it will probably pick them up somewhere else.

(.)

(12:55) PAULA: So [the, the

(12:55+)LOU: [I think that's what happens. I'm not sure about that but [it's not going to

(12:57) PAULA: [So if I charge this thing, so where have the electrons gone on this thing.

(13:01) LOU: ((demonstrating with his hands)) So you have your cat hair [and your stick.

(13:02) PAULA: [So all of a sudden it's going onto the [stick.

(13:04) LOU: [They go from onto the [stick, and then

The PBL group realizes that during the static electricity demonstration, electrons are transferred from the cat hair to the plastic rod. Next, they figure out what happens to the extra electrons on the rod.

(13:05) CINDY: [They go back to the air and [then,

(13:06) PAULA: [And then I have a whole bunch of these. ((continuing to diagram on the board)) (.) [xxxxx.

(13:08) LOU: [Well they stay on the stick and I don't know where the cat hair picks up it's electrons.

(13:11) CINDY: ((pointing to paper on table)) But (well) when the stick gets (into) here eventually this thing, this, (.) the stick puts them on here, but eventually this doesn't work anymore.

(13:18) LOU: Yeah.=

(13:18+)DEAN: =Yeah because they were,

(13:19) CINDY: Because (they) went back to:=

(13:20) DEAN: =Because they were dissipated,=

(13:21) CINDY: ↑Yeah.

(13:21+)DEAN: =into the air um, [as soon as, as soon as he takes the cat fur and puts it on the table,=

(13:23) CINDY: [(The ground other things)

(13:24) DEAN: =It can pick up electrons from the table.=

(13:26) PAULA: Yeah well that makes sense.

Paula concludes (Uy, 13:26) that it is making sense. The electrons from the cat hair go to the plastic stick, into the air. The cat hair picks up extra electrons from the table. They seem to have built a picture of where the electrons come from and where they end up. However, the more difficult questions do not get fully answered during this conversation.

***"They're not just floating around." [electrons] (8:32)***

*Origin and Discussion*

Soon after the 'where do electrons come from' question, Paula makes a questioning statement (S) "they're not just floating around" at 8:32. Dean answers "no" (As, 8:35), but they do not discuss the issue further. Later at 11:26+, after discussing the plastic rod, Paula asks a direct question (Qs, ) about electrons in the air. Bo responds (As/S, 11:29) and Dean repeats his "no" and begins to discuss the idea of grounding and whether electrons are taken or not (11:30-11:32).

*Solution*

The floating electrons question is addressed again after the bonding question comes up when Dean mentions that electrons get dissipated into the air at 13:21+. This is not scientifically accurate (Personal Communication). Dean changes his argument at 13:24 by saying the electrons are picked up by the table (and Paula affirms this idea by saying it makes sense (Uy, 13:26).

(11:26+)PAULA: There's not just free floating electrons are there?
(11:29) BO: °Well they're (groun[ded.)°
(11:30) DEAN: [No but every[thing, everything-
(11:30+)PAULA: [They're not just like all over the place.
(11:32) DEAN: ((Hands on back of head.))Everything is at a different potential? (1) Um:, and normally it's the earth ground potential. (1) But you're changing the ((BO crosses arms))potential of one thing and the potential of the other, (.) in the same way. ((motioning with hands)) (.) You know you're, you're increasing the voltage over- (.) °well not voltage ah:.° ((waves away the comment with both hands)) Okay now how (can we) let me rephrase this to help you. Um::. ((He taps his fingers on the table))
(2)
...
(13:20) DEAN: =**Because they were dissipated**,=
(13:21) CINDY: ↑Yeah.
(13:21+)DEAN: =**into the air** um, [as soon as, as soon as he takes the cat fur and puts it on the table,=
(13:23) CINDY: [(The ground other things)
(13:24) DEAN: =It can pick up electrons from the table.=
(13:26) PAULA: Yeah well that makes sense.

In summary, the question of free-floating electrons is not directly explained. Dean firmly answers "no" twice, but later, brings up a misconception (see added boldface above) by saying that the electrons are dissipated into the air. Dean

soon adds a more accurate conception of where the fur picks up electrons - from the table. However, no one connects this idea to the dissipation idea. Apparently, the student teachers believe that the rod's electrons go to the air, while the fur picks up electrons from the table. It is not clear if they now also think, more accurately, that the fur and rod are neutralized when they touch the table. Plus, the idea of electrons moving around the hand that touches the rod and fur is not considered.

***"But, aren't you going to be changing the chemical composition...?" (8:40)***

*Origin*

The student teachers generate a complex question through their PBL discussion, about why the chemical properties of the rod and fur do not change when they are electrically charged. The birth of this question was quoted earlier, under "where are they coming from?": Jenna asks the preservice teachers to write down learning issues (7:50), and then Paula asks where the electrons are coming from (8:31). After more talk about learning issues (e.g., 8:55), instead of answering the question, Lou (10:21) lets Dean answer it, but Dean asks a process question (Apro, 10:23) instead. At 10:27, Paula asks her question again:

(10:27) PAULA: And why doesn't it change the chemical composition if you're taking electrons away and why (doesn't) it all of a sudden want to bond with something.
(10:33) LOU: (Oh) I can answer that part.
(10:35) PAULA: [(There's two questions in there.)]
(10:35) DEAN: [Well between Lou and I!]
(.)
(10:37) (PAULA): Hmph.

*Discussion*

Lou and Dean both utter Puffs (10:33 and 10:35 respectively)--saying they know something, but not revealing it. The discussion turns back to where the electrons are coming from, until Paula brings up the bonding topic again at 12:02.

(12:02) PAULA: [And you're not, you're not going to make it want to bond more with something else?
(12:06) DEAN: You will. (2) Because, if you change the elec-
((PAULA laughs, DEAN covers his face with his hands.))
(12:12) CINDY: So it-
(12:13) DEAN: Um not- (1) hhh
(12:16) CINDY: (Or) you're not taking it=
(12:17) DEAN: =I don't know how to explain this [in few sentences without taking, an hour.

By this point the group is having trouble answering the questions. Dean says 'yes, the material will change it's bonding behavior' (12:06), but then Paula laughs and he covers his face. Cindy and Dean start to form sentences for the next few turns, until Dean says he can't explain it without more time (12:17). This utterance was coded as a Puff, because he seems to be saying I know this, but it

will take me too long to explain it to you. However, by this point, it appears (12:06, 12:13, 12:17) that Dean does not really know how to explain it at all.

*Solution*

They return to the possible change in behavior of materials during static electricity a minute later:

DEAN: (.) But(.)temporarily we can move electrons around, AND, you are changing the ele- the electro-chemical potential?=
(13:40) PAULA: Um hm.
(13:41) DEAN: =For that compound.
(13:41+)PAULA: Um hm.
(13:42) DEAN: And, you may or may not cause it to react to something by doing that, ((marking points off on fingers)) but it's going to depend what the substance is, what it's in the presence of, (2) (you know) a WHOLE bunch of other stuff but you can- you WILL change it's chemical behavior.=
(13:53) PAULA: =So why is it going to do that. ((raising arms to head and then dropping them to sides))
(13:55) DEAN: [What.

Dean states that during the imbalance of charges the materials will react differently than before and the chemical behavior will change. He perhaps fudges this by saying it will depend on many other factors (13:42), and when Paula asks him to explain again (13:53), Dean stalls (13:55). Then Lou begins, and the group makes progress:

(13:55) LOU: [(If it, if it) it's really not, hanging onto these electrons, very hard=
(13:58) DEAN: Yeah.
(13:58+)LOU: =cause it doesn't want them that much. Otherwise it wouldn't (give up to this) plastic stick.
(14:02) PAULA: Okay [so?
(14:03) LOU: [So, because it loses these really (.) ((brushes with hand)) light ones, it's not going to bond to anything really.
(14:08) PAULA: [(It's)
(14:08) LOU: [If you, were able to pull off, to pull them off. °I don't know how you would be able to do that.°
(14:12) DEAN: The core electron.
(.)
(14:13) LOU: Then it would be really [xxxx=
(14:14) BO: [(So you're losing)
(14:15) CINDY: You're [losing the ones outside.
(14:16) LOU: =[The stick's not going to pull [those off.
(14:17) BO: [°Yeah.°
(14:18) PAULA: Okay.

Lou gets an idea started that seems to remind Dean of the concept of "core" electrons, which the group accepts as a tenable idea. This segment above

suggests a collaborative knowledge construction process as the whole group is involved in completing each other's sentences. They conclude that because the electrons are not core electrons but just some light ones on the outside, the object's bonding behavior is not affect ed. Then, Dean inserts his old opinion again, saying:

> (14:20) DEAN: And you, [you are increasing it's reactivity.
> (14:20+)(PAULA): [(I I)
> (14:23) PAULA: Okay.
> (14:23+)DEAN: I would bet. But not to an extent where it's going to blow up on you.
> (14:27) PAULA: So it doesn't care really either way but it's kind of like well if they're there.

Paula agrees with Dean's slight reversal of opinion (14:23). Then he de-emphasizes it by saying the reactivity doesn't occur to a drastic extent (14:23+). Paula produces a vague remark (14:27), and a few sentences later she says "but otherwise it's like whatever" (14:35+). It appears that Paula, uncharacteristically, might be uncertain again, but she is going along with the explanation.

**Closure of PBL Discussion: Shift in Learning Issues**

Usually, at the end of a PBL session, the participants review the learning issues—ideas to further investigate and learn about--and assign people to particular issues for the week. At the end of the discussion here, the questions about science became learning issues in an unusual way. The facilitator wrapped up the discussion, saying that it was valuable time spent on scientific ideas.

> (14:54) JENNA: Well okay let's let's let's (turn) it off for here right now but let's think about this more because I think this is good because you do need to think about the things, that are important for him to tea:ch and, how, we think he needs to teach them.
> (15:06) PAULA: Uh hm.
> (15:06+)JENNA: And these are all, (.) >the the< domain knowledge is incredibly important, to, (.) to (teaching). So, I [found this, very valuable.
> ((PAULA smiles at camera))
> (15:13) DEAN: [So, so what IF, for next time (3) I'll split this up with Lou since he seems to be the other person who, (.)
> (15:23) JENNA: Well?
> (15:24) DEAN: [And we-

At 15:13, Dean volunteers for a learning issue, and he recruits Lou as well. His comment that "since he [Lou] seems to be the other person who" would seem to end in something like 'has a grasp of this' or 'knows about this,' but Dean does not finish this sentence. Perhaps because it would be insulting to the remaining three student teachers around the table. Jenna asks for the rest of his sentence (Tqc, 15:23), but then goes on to request a more specific learning issue.

(15:24) JENNA: [We can we can make it a learning issue something
that we need [to write about.=
(15:26) DEAN: [Okay.
(15:27) JENNA: =↑So, where do electrons come from
(1) ((CINDY writes on whiteboard))
(15:30) DEAN: Well how does conduction and, how >does (it all)<
work anyhow.
(.)
(15:33) JENNA: What?
(15:33+)DEAN: I mean how does THIS, (.)((waving hands at papers
on table)) all work anyhow, is I think the question we could
ask. ((JENNA nodding)) And you can quote me on that.
(3)
(15:43) BO: [xxxx
(15:43) PAULA: [(I guess) how does static electricity work °(I guess)°
((PAULA, LOU, BO, and then DEAN all look at the camera))
(15:45) DEAN: Oh you don't like my, ambiguous (slang)?
(3) ((BO chuckles))
(15:51) DEAN: I was priding myself on that.

Interestingly, they don't list all the questions, but instead present a very general question of 'how does static electricity work.' The learning issues written on the whiteboard were: 1) "Where does negative charge come from – why not change chemical compound?" and 2) "How does it all work (static electricity)." The first learning issue is not clearly stated—it asks where the charge comes from, not where the electrons come from, and it asks why the compound is not changed, instead of the chemical "composition," and "behavior" (terms they used earlier). The second, very general learning issue is interesting given that they correctly solved some of their queries but not others. Perhaps, they did not realize that they had reached the correct conclusions on some questions and not others. Another possibility is that this question "how does it **all** work?" (emphasis added) shows that they felt they lacked a broad, foundational knowledge in this area of science.

Next, Cindy turns the conversation toward the crux of the assigned problem, how to teach static electricity.

(16:15) CINDY: OH. How does this apply to like what the:y're- (.)
WHO cares. (1) ((? laughs, JENNA nodding)) I- Like if
you're sitting here who cares they're going to be like great.
I'm going to poke Paula and she's (getting) a shock who
cares. What-How is this going to help them in the real
world kind of.
(16:29) DEAN: °Okay, (let's- where is it)°
(16:30) CINDY: That would be my thing to change.
(16:32) (JENNA): (Okay, xxx for you) ((She changes a part of the
whiteboard))

The next four minutes are spent exploring the idea of teaching about relevant, real-world issues, and the many shades of meaning of the term 'authentic instruction' (see Derry et al. & Steinkuehler). Basically, the science questions turn into instructional questions as the next section of the paper will demonstrate.

**"The term *static electricity* is scary:" Focus Shifted throughout Remainder of Problem**

After the initial PBL discussion during which the student teachers discussed and hypothesized about five questions regarding static electricity, the topic did not arise again. The shift in focus from science questions to instructional questions is notable, yet not surprising. The science was not the focus of the problem, remember, but an instructional solution to teaching static electricity was. The turn to instructional issues is also reflected in the final paper:

> We feel that Blair should focus less on individual issues, such as static electricity and more on providing his students with a deep understanding of certain models. This would enable the students to understand and incorporate all knowledge of static electricity concerning atoms, charge, and movement of electrons. Specifically, Mr. Johnson can use static electricity to further explore the structure of the atom in terms of electron transfer and flow (or lack thereof). We shall term this approach "deep knowledge" from this point forward.

The student teachers were quite aware of the importance of student conceptions about static electricity, but did not mention the scientific issues that came up during their initial discussion.

> Static electricity is a difficult subject to fully understand because it involves invisible processes that require the development of mental models in order to get a feel for what is happening during the process. Learning about static electricity involves understanding how and why electrons flow from one substance to another and the consequences of such an action. Before a unit on static electricity can be taught, students would have to have a firm grasp on the structure and function of an individual atom and its electrons. For this to be most successful, Mr. Johnson must be aware of his student's misconceptions about static electricity and about models of the atom. He must also avoid using teaching strategies that will reinforce these misconceptions or even give students new ones.

Dean wrote the draft of this section of the paper. Most of the other sections were then edited and supplemented before the final version. Dean's section was not edited for content, and only a few minor stylistic changes were made in the final version.

The final paper addresses misconceptions quite well (see excerpt of paper in Appendix 3). It explains how both words from the term "static electricity" are misleading: 'electricity' refers to a wide range of phenomena, and the 'static'

(unmoving) aspect is irrelevant to the occurrence of charge separation (or imbalance). The student teachers have learned that 'static electricity' is not 'static.' The paper goes on to describe use of models and naïve conceptions associated with electricity and also with the model of the atom, however it does not address any of their own five initial questions from the first day of PBL.

## Section 2: Use of Resources

The purpose of this part of the study was to gain insight into the ways preservice teachers deployed resources for researching subject-matter information, how the preservice teachers presented themselves as resources and whether outside resources were used, and to identify the status of those resources in the learning community. Our analysis of preservice teachers who are in transition from the teacher education program to the 'world of teaching' is intended to inform teacher educators about the ways future professional teachers are able to search for domain specific information and to inform the instructional designers of this educational psychology course.

### Science Mentor

The science mentor provided useful information for the student teachers, but interaction was limited to two entries on the online discussion tool. Jenna, the facilitator, initiated one entry and the other was a reply from the mentor to Jenna (see Appendix 4).

The first online entry was initiated on March 30th 2000, after the first PBL discussion about static electricity. The facilitator wrote the science mentor on the discussion board and summarized the science group's proposal that static electricity is probably not a central concept that students need to understand. She added that the science preservice teachers are currently discussing ways to try using a model of the atom as the central concept and to use static electricity to illustrate it.

She inquired if the mentor agreed or disagreed with the preservice teachers' consensus that static electricity is not a central concept that students will likely transfer to other contexts beyond the lesson depicted in the video case. She proceeded to ask what the preservice teachers should teach and for what purposes this information be used by students and whether students need to know about static electricity.

On April 6th 2000, the mentor responded on the discussion board. He agreed that static electricity was not a central concept to teach and further explained that he thought the core idea is electric charge and that it is related to topics such as chemistry. However, if a relation is to be made to physics, the core concept is electric charge, because it relates to both voltage and current. (See Appendix 4 for the transcript.)

Soon after this, the student teachers take up the mentor's idea without communicating on the discussion board. In Dean's written summary of his individual research on the topic of misconceptions for the PBL group, he states

that static electricity is a "scary" and "intangible" subject for students and educators (full text in Appendix 3). "Scary" because it would mean decoding confusing concepts and language, and "intangible" because it means dealing with student understanding based largely on misconceptions. He also quoted the mentor's proposal for focusing on electric charge and the atomic model rather than static electricity: "Since there is only two days for the instruction to take place, it should focus on developing the student's understanding of electrical charge and how that relates to their pre-existing model of the atom [From mentor]." Dean's proposal is edited for style, but the content remains the same in the students' final group paper that is posted to the discussion board on the deadline of April 15th 2000.

The science mentor was not used as a "live" science resource by the students, but instead was cited the way a static textbook might be referenced. The students appeared to learn from and agreed with the mentor, but did not interact with him, ask him questions or follow up a discussion.

The fact that Dean quotes the mentor in his summary paper and the group's final paper suggests that the preservice teachers trusted the mentor's opinion. The facilitator also displayed confidence in the mentor in the first week of PBL discussion stating:

> (9:52) :Jenna [Before we go] (1) further, write write down what you're thinking about. >And before we go further let's put down the learning issues because I think that's something there are things that we need to KNOW that you're saying we don't know that we can ask our **mentor**.< So, what are those things so that she can write up our learning issues. ((to PAULA)) You were asking a question and I was thinking so I don't know (what it was)=

**Facilitator**

The facilitator was a critical resource in the PBL discussion, because being perceived as an "authoritative" voice, she had the capacity to encourage the preservice teachers to pursue the scientific questions or deter them from doing so. From time 7:00 to 15:54 in the talk about science, she encouraged the preservice teachers to take the "risk" of pursuing the questions they had about static electricity. She explicitly assured the preservice teachers that the domain knowledge is an extremely important aspect of their course, despite the fact that the course she was facilitating is a course on the learning sciences, rather than a science methods course. Very frequently in the PBL talk, the preservice teachers sought her approval to talk about science. For example:

| | |
|---|---|
| 7:48 Lou | ((to JENNA)) So this has nothing to do with this so. ((LOU laughs)) |
| 7:50 | ((Reply by Jenna )) |
| ... | |
| 8:40 Paula | But, aren't you going to be changing the chemical composition? (.) (But) I'm sorry. |

8:44 ((Reply by Jenna))
...
10:08 Paula I was asking a science question (is that okay?)
10:10 ((Reply by Jenna))

Based on the excerpts below of the facilitator's comments, it is evident that the facilitator is molding the domain questions into the PBL structure by labeling them as learning issues. She encouraged the preservice teachers to think about making the science questions into learning issues for further research.

7:50 Jenna Oh I think it could.? I think it could because it may have been a question, that the ≠students might have that (the students can) address.
8:04 Jenna I- any idea is a good idea ∞you know.∞=right now=
8:06 Jenna =We're just brainstorming. (1) So (pose the risk)
8:44 Jenna ((waving pencil)) Well I think we have a
8:47 Jenna = I think we have a couple of things, going on here, that we need to (help). That we need [to slow down and maybe EVEN if we can write down too, the **learning issues**.=
9:52 Jenna [Before we go] (1) further, write write down what you're thinking about. >And before we go further let's put down the **learning issues** because I think that's something there are things that we need to KNOW that you're saying we don't know that we can ask our **mentor**.< So, what are those things so that she can write up our learning issues. ((to PAULA)) You were asking a question and I was thinking so I don't know (what it was)-
10:10 Jenna A science question is valuable if it pertains to this. If if it's something we think that they need to- that the kids might be wondering about too that.
14:54 Jenna Well okay let's let's let's (turn) it off for here right now but let's think about this more because I think this is good because you do need to think about the things, that are important for him to tea:ch and, how, we think he needs to teach them.
15:24 Jenna [We can we can make it a learning issue something that we need [to write about.=

In many instances (see excerpt below), Jenna, who was a first-year doctoral student in Educational Psychology at the time of the course, revealed her lack of knowledge in the science domain. She had been a teaching assistant previously while pursuing a masters degree in the same field. At 8:55, Jenna tried to mediate the process for the student teachers about the possible issues that they wanted to change in the redesign of the instruction that was shown on the video, but had difficulty verbalizing the problem at hand and called on Lou to complete her sentence. At 15:06, she stated that she found that domain knowledge is incredibly important to teaching and had learned something from the preservice teachers' PBL discussion.

8:55 Jenna	We need to:, ah, make sure that we get down, that, one possible thing we want to change is to explain, (.) ah why (.) different materials=
9:05 Jenna	=accept, (.) different kinds- ((to LOU)) You say it.
...
15:06 Jenna	And these are all, (.) >the the< domain knowledge is incredibly important, to, (.) to (teaching). So, I [found this, very valuable. ((PAULA smiles at camera))

We argue that because the facilitator's relationship to the science domain was not authoritarian, it enabled the preservice teachers to pursue the science question. This non-authoritative position provided the possibility of critical "interanimation" of science talk among members of the PBL group. Interanimation (Warren and Rosebery, 1996 pp.100-102) is a set of varied discourses comprising agreement, opposition, authority, parody, irony and so on that coexist as different participants engage in an interaction allowing for change and development to occur during the talk. In Warren and Rosebery's study, their analysis of classroom science talk depicts a situation where the teacher's nature of talk in an earth science lesson was authoritative and therefore, denied the possibility of sustained, critical interanimation between the teacher and students' viewpoints. This finding is in contrast to the PBL talk in which the facilitator did not claim authority over the domain knowledge. We claim that this non-authoritative position on the part of the facilitator, allowed for a sustained interaction about science among the student teachers as she encouraged them to pursue the science questions.

**Web**

Dean presented how he used the Web as a resource at the second week's PBL session. When asked by Jenna about how valuable the Web site was that he found, he mentioned that he knew enough about the topic to know whether it was a good Web site. He also mentioned that he was not concerned about who puts up the Web page as long as it is accurate information. In Dean's summary of individual research, he quoted an electrical engineer's site (Beaty, 2000) multiple times. Based on the engineer's opinion of textbooks, Dean writes, "Not only is static electricity a relatively intangible topic for students, but also the language used by textbooks is often confusing and helps to promote these misconceptions." Also, Dean cited this Web site regarding the term static electricity: "Before teachers can confront student alternate conceptions, they must define the term static electricity." Dean also added that "teachers must confront several common misconceptions in order for students to have a better model for understanding static electricity...In addition, static electricity is not electricity, which is static. ...Instead of using the term static electricity, it would be more correct to discuss charge separation."

**Physics Professor**

Lou on March 28th 2000 reported to the group that he asked his physics professor about why certain items give negative charge while other items give positive charge (25:53 to 26:30). He said that the professor thought that it was related to

electric negativity and that the problem was complicated. "I asked the physic professor about that (.) he didn't know so (.) (all students laugh). Probably something to do with electronegativity and he never (xxxxx) a satisfactory answer (.) I know that I never have, so (.) we both kind of assumed that it was kind of complicated. So I looked at that." Lou seemed to think that the question he asked was a complicated question that even experts had difficulty explicating.

**Textbook**

Dean informed the group very briefly that he looked up a college Physics textbook, but static electricity was not mentioned at all. However, in his 3 chemistry textbooks he found information about the atom. The student teachers read about static electricity in the physics book that was also used in the video-case classroom, written by Hewitt (1997). By saying that "static electricity was not mentioned at all," Dean was already showing agreement with what was stated on the Web site "Not only is static electricity a relatively intangible topic for students, but also the language used by textbooks is often confusing and helps to promote these misconceptions."

**Student Teachers**

The preservice teachers in the PBL group were from different science backgrounds and had varied amounts of expertise in physical science. They served as disciplinary resources for each other. Prior to this course, they have been in the same science cohort for the past two semesters; therefore we assume that they knew one another well. For example, Dean's expertise was in chemistry, and Lou's expertise was in physical engineering (see Table 4). Arguably, that makes them the authority on the current subject matter for the group. The two biology majors (Paula and Cindy) and Bo, who specializes in earth science, might depend on Lou and Dean for information about electrostatics.

Table 4

*Anecdotal Information about Preservice Teachers' Science Backgrounds*

| **Preservice teachers** | **Science Background** (based on interview transcription with the student teachers) |
|---|---|
| Dean | Dean has taken introductory chemistry, introductory analytic chemistry, all the organic courses that are offered at the University of Wisconsin-Madison. He took two semesters of P-chemistry lecture, two semesters of P-chemistry lab, intermediate inorganic and at the time of the course was taking advanced analytic. He has also taken Astronomy 104, Physics 207 and 208, which are calculus-based classes. |
| Lou | Lou started out at the Department of Engineering for about two years before deciding that he did not want to become an engineer and decided to go into education. He has taken classes such as Chemistry 109 and Chemistry 110 and an array of Physics classes such as 207, 208 308, and 241 just to name a few. |
| Bo | Bo took five years of science in high school. He has also taken |

| | |
|---|---|
| | subjects, such as geology, mineralogy, glaciology and entomology just to name a few. He aspires to become an earth science teacher. |
| Cindy | For her undergraduate studies, Cindy majored in zoology and psychology. |
| Paula | Paula likes biology and was a pre-medical student for three years before deciding that she did not want to see sick people nor treat illnesses and go to school for another nine years. |

Table 5
*Degree that Preservice Teachers Participated in Scientific Discourse*

| Preservice teachers | Turns of science talk | | | | |
|---|---|---|---|---|---|
| | As | Qs | Aa | Qch | S |
| Dean | 30 | 0 | 11 | 0 | 2 |
| Lou | 7 | 1 | 3 | 0 | 2 |
| Bo | 1 | 0 | 3 | 1 | 1 |
| Cindy | 4 | 2 | 5 | 0 | 0 |
| Paula | 7 | 10 | 9 | 1 | 3 |
| **Total** | **49** | **13** | **31** | **2** | **8** |

The preservice teachers presented themselves as resources in the PBL learning community with distinct roles. Also, each role was reacted to and thus instantiated by other members of the group relying on or challenging that function. Next, we describe how each participant enacted a specific resource role during PBL discussions.

*Dean*, who uttered the most science answers, presented himself as an expert among his peers, as shown in the table of transcript excerpts below. He also considered Lou, who has a background in chemistry, to be at a similar level and offered to share the research workload with Lou. He utilized many physical science terms, such as "earth ground potential" and "voltage." The body language of other students, such as Bo at 11:32 crossing his arm, possibly indicated that these were not terms that everyone was comfortable with, thus creating a barrier between Dean and his peers (Levine & Mooreland, 1991).

The researchers' initial impression of Dean, based on interaction analysis, was that he seemed to know a lot about science, but we were not sure if he really did, or if he wanted the group to think that he was an expert. We also agreed that he was a dominant force in the group. One researcher present commented, "Is he taking over this class or what?!" Another researcher noted that his peers enabled him to have authority: "The people are allowing it. It's co-constructed. They're looking at him [Dean] for the answer. They're not distributing the science resource authority at all."

Dean's peers and the facilitator also considered him to be a resource in the group. For example, at 7:08, 8:18 and 8:31, Paula asked a direct or indirect science question, after Dean made a science statement. Lou also suggested that Dean could answer a science question uttered by Paula at 10:21. The facilitator, for example at 7:15, nods in agreement with Dean's statement.

Table 6
*Dean Presents as a Scientific Resource*

| Timecode | Name | Code | Comments | Transcription |
|---|---|---|---|---|
| (10:35) | DEAN | Up | | [Well between Lou and I!] (.) |
| (11:32) | DEAN | As | Claims to be an expert. "let me rephrase this to help you." | ((Hands on the back of head)) Everything is at a different potential? (1) Um:, and normally it's the earth ground potential. (1) But you're changing the potential of one thing and the potential of the other, (.) in the same way. ((motioning with hands)) (.) You know you're, you're increasing the voltage over- (.) ((Bo crosses his arms)) °well not voltage ah:.° ((waves away the comment with both hands)) Okay now how (can we) let me rephrase this to help you. Um::. ((He taps his fingers on the table)) (2) |
| (15:13) | DEAN | Qp | Dean is saying that he and Lou are the resources in the group. | [So, so what IF, for next time (3) I'll split this up with Lou since he seems to be the other person who, (.) |

It is also evident that at 14:36, despite Dean's confidence in providing science answers to the group, there was tension in Dean's talk "…Um the, energy °ah, I'm getting this (confused x).°" As he continued to defend answers to questions asked, the vague explanations left him vulnerable to giving up the notion that he would solve all the groups' questions about static electricity.

*Paula* played the role of non-expert and questioner in the group. At 7:45 Paula says "I was explained that once but don't ask me to repeat it ((PAULA chuckles)). She confessed that she did not have the expertise in the group as resource for the science question that they discussed. Although Paula admits that she is not an expert in static electricity, she was an active participant, constantly questioning and challenging Dean. She asked the most science questions among her peers uttering 10 or 77% of the questions. For example at 8:30, Dean say "[So it takes the electricity and [xxx." and Paula asks "[Where are they coming from?" Nevertheless, Paula also agreed with Dean many times throughout the talk, presented as Aa in the transcript. Paula was also actively answering science questions, participating in 7 out of 49 turns (14%) of science answers. From these

percentages of participation, we argue that Paula held the role of the active "questioner" of the group.

*Lou* was the expert collaborator and questioner in the group. His first utterance asking how static electricity actually works, presented himself as a chemistry resource who did not have answers for everything. For example at 7:29, he displayed his desire to know about science and asked his questions publicly while professing his ignorance on the subject matter "Ah no. Ah? (.) The one thing I was wondering when people do this is why is there things °xxxxxx° >[I] don't know why.<=." At other times, he presented himself as a resource by participating in 7 turns of science talk, for example at 10:33 Lou said "Oh I can answer that part" and at (13:58+) "=cause it doesn't want them that much. Otherwise it wouldn't (give up to this) plastic stick." Lou also displayed acceptance of Dean being the subject matter expert and afforded him that role at 10:21 "You can answer it," when Paula asked at 10:17 "Where do the electrons come from that transfer. (2) ((DEAN raises his hand and then puts it down and tightens his lips))." Lou is a "collaborator" asking an important question at 7:39, which led to the group's discussion about static electricity for the next 7 minutes. He was also active in answering science questions, but was not overbearing in his contribution.

*Cindy*, who took notes on the whiteboard during this PBL discussion, seemed to be the synthesizer for the group. She was an active contributor to the group's talk, but at 8:12 quickly announced to the group that she is a biology expert and not a physics expert (Ad). For example at 8:18:

(8:12) CINDY °(I don't know isn't-)° ((to group)) Isn't there a rule like on the x table that talks about- I'm biology so
(8:17) DEAN [No. (.) No.
(8:18) CINDY But >[DON'T metals always accept electrons?<

Also, she constantly validated her peers' science answers. Cindy asked an average number of science questions and answered an average number compared to others in the group. As a synthesizer in the group, when she agreed with a statement, she would repeat the answer, such as at 7:10 Cindy repeated "The Bohr model," and she would complete utterances started by others or further elaborate these utterances, for example at 10:53, 11:00 and 13:11.

(10:51) PAULA You're transferring electrons.
(10:53) CINDY Some[times you xxxxxx.((she moves her hand back and forth in the air))
(10:56) LOU (I have a:) like on the conductor, on this little ball that was xxx=
(10:59) DEAN =Yeah.=
(11:00) CINDY =[They're only xxx (touch).
...
(13:08) LOU [Well they stay on the stick and I don't know where the cat hair picks up it's electrons.

(13:11) CINDY ((pointing to paper on table)) But (well) when the stick gets (into) here eventually this thing, this, (.) the stick puts them on here, but eventually this doesn't work anymore.

*Bo* displayed a peripheral role in the segment on science talk, asking and answering the least science questions. He gave only one science-related answer at 11:29, but was cut off by Dean at 11:30. Cindy also cut him off during a science question at 14:14. His peers' tacit practice of cutting him off while he was talking perhaps suggests that his contribution was not highly appreciated. Another time he tried to participate in the science talk and challenged Dean at 10:47.

**Resource Use Results**

The preservice teachers directly utilized the facilitator, the World Wide Web, textbooks, physics professor and themselves as resources. The student teachers learned from each other and enacted varying resource roles during their discussion. We found that the facilitator interceded on behalf of the group with the science mentor, the mentor responded, and the group did not interact further, although they incorporated his idea. We also discussed the status of each of the resources and with how much authority they were perceived.

## Section 3: Preservice Teacher Learning

**Comparison of Student Teacher Understanding to Experts' Views**

Based on the data sources available, we will summarize participants' understanding about static electricity and compare their ideas to expert answers.

We found that student teachers' understanding of the model of the atom and the involvement of electrons in static electricity was solid. They were able to draw a simple model (12:21), hypothesize about it and make predictions (12:29, 13:55). They also were able to explain, after a while, how electrons are involved between different materials (e.g., 13:24). This knowledge is at a level where a reader could look up "atomic model" and "electricity" in a physical science textbook and not know anything more than the teachers displayed. For example, the textbook used in the high school classroom shown in the video case says "when a rubber rod is rubbed by a piece of fur, electrons transfer from the fur to the rubber rod. The rubber then has an excess of electrons and is negatively charged" (Hewitt, 1997).

Many questions arose that the teachers did not figure out during the session and did not return to in later classes. They did not reach an understanding about why hair and plastic are effective static electricity demonstrators. Dean gives a partial answer during the conversation, but no one connects it back to the original question. In further discussions, paper versions, and online discussions, the teachers do not return to the topic. Also, they make progress in figuring out how the materials are balanced again, but do not decide what is going on with the air and whether electrons can float around in the air or not. Similarly, they make headway about whether the chemical composition, behavior and electrochemical potential of the materials are changed during static electricity, but they do not reach conclusions during the video or in later sessions.

The researchers' initial impression during an interaction analysis session was that the teachers did not fully understand the topic. One researcher noted, "...they're illustrating in their talk the relationship between that cognitive science issue and the need to have domain knowledge, deep knowledge of the subject. And even these science people don't know - don't have that clearly. And that's a problem when you're wanting people to understand." Another researcher perceived that, "Dean is displaying expertise maybe he doesn't have. It's an interesting question if you strip off electrons why it wouldn't change bonding behaviors."

These unsolved topics are indeed quite difficult. Two science experts felt that the issues were "not easy" and "make you think" (Personal Communication). One methods teacher explained that these ideas are hard to reason about because they involve the intersection of two "usually distinct domains (chemical bonding and the physics of electrostatics)...that are normally taught in isolation from one another" (Personal Communication). In fact, the issue of lost electrons during static electricity affecting bonding behavior is a question rarely considered. This rarity suggests that the questions student teachers generated were born of deep reasoning about the topic.

What are the answers to these hard questions? We checked with experts and found that even they disagreed.

Table 7
*Experts Answer the Group's Questions*

| Wording of our question /Expert's title | Expert answers |
|---|---|
| **When you strip electrons off something, for instance when you rub a rod with fur to make static electricity, once those electrons are temporarily gone, how come it doesn't affect the way the atoms bond?**<br><br>Physics Graduate Student (Personal Communication) | Again this is an average you really aren't stripping off enough electrons to change the whole solid. So a couple of atoms will change their bonds a bit. This is just like having a few extra ions in the solid and is quite common. A good example on this level would be how one can neutralize a rubber rod that has a charge. If you light a candle and hold the rod above it the rod will return to a neutral charge. What is happening is that the reaction in the burning flame is giving off several ions which are traveling up in the heat. When they encounter the rod which we will suppose has an overall excess of electrons some of the ions can grab an electron on their way by.<br>For this I have to move to a slightly different model of the atom. There are electrons that are involved in bonding and there are electrons that are not but are still in the outer orbital shells. The latter have a higher amount of energy than the former. Physicists call these "conduction-band electrons," because they have enough energy to come loose from the atoms and conduct. The electrons that are involved in bonding are typically lower energy, and remain slightly closer to the nucleus. |
| Science Educator with | I think you're question is an excellent one, though. It does seem as though with fewer electrons around, the bonding would happen slightly differently. So I'm really not sure what's happening. Perhaps energies at which atoms will bond in a |

| | |
|---|---|
| Strong Science Background (Personal Communication) | stable way shift a bit when there's a current flow in a conductor or when you're stripping electrons away from an insulator. Again, I'm not sure. |
| Electrical Engineer (Personal Communication) | It should, since it converts the atoms into ions. If those atoms were already part of much larger molecules (as they would be in rubber, plastic, fur, etc.) those molecules will now have an ionized spot. Since the atom in question was already bonded covalently into the rest of the molecule, the microscopic forces would need to be very strong if those bonds were to break. I don't know enough about chemistry to tell you whether ionizing a small part of a large organic molecule can cause atoms to break off from it. |
| **Does charge imbalance affect chemical bonding? Chemical behavior? Reactivity? Electro-chemical potential (and how)?** Electrical Engineer (Personal Communication) | Yes. For example, neutral sodium atoms are highly reactive, but if they lose one electron (becoming positively electrified), they act very inert, since the remaining electrons form a complete shell. Chlorine is similar, it is reactive when neutral, but becomes inert if it GAINS one electron (this fills the last hole in the outer electron shell.) This is a topic in chemistry: electrochemistry. Rubbing two objects together is essentially causing electrochemical reactions in the molecules on their surfaces. On the other hand, the number of imbalanced charges on the surface of an object is very small compared to the number of atoms in the surface, to say nothing of the number of atoms in the whole object. Electrified surface atoms would act like a very slight impurity, maybe in the range of parts per billion or less. The electrical forces caused by imbalanced charges are VERY strong, so you only need extremely tiny amounts of "charged" material in order to create sparks or to attract lint, etc. |
| **For example, can you get extra electrons from the air? Are they floating around?** | |
| Physics Graduate Student (Personal Communication) | No. |
| Science Educator with Strong Science Background (Personal Communication) | The electrons definitely do not dissipate into the air. |
| Electrical Engineer (Personal Communication) | Yes and no. Gas made of nitrogen and oxygen molecules not conductive (it doesn't contain free charges.) However, cosmic rays are always bashing air molecules. |

Having the science experts provide different answers and say that the questions 'made them think,' plus the view from the science education field that these are advanced issues that are usually taught separately, provide evidence for the claim that the teachers were reasoning deeply about science.

Another hypothesis arising from this analysis is that the preservice teachers did not regulate the state of their understanding thoroughly. A few statements occurred simply stating if something made sense (Uy) or not (Un). Yet, the participants did not summarize their learning issues separately at the end of their session. One out of two issues to research further was 'how does static electricity

work' rather than the probing questions they came up with during the discussion (cf., Table 3).

**Discussion**

*1) Scientific Discourse*

We identified a variety of ways that student teachers identified a need for knowledge and ways that they resolved it. The scientific discourse was quite student-centered in that the student teachers were asking the questions, not the facilitator, and most often after they made a query or questioning statement, the next utterance was a science comment (As) from another student teacher. Prior work on questioning found that even student questions to teachers tends to be rare (Dillon, 1988), let alone student questions to students. The predominant form of discourse in classrooms is IRE, or a teacher Inquiry, a student Response, and a teacher Evaluation (Cazden, 1988; Mehan, 1979; cf., Lemke, 1990). Our problem-based learning course had a different format for the preservice teachers and higher expectations for the participants as professionals. We were pleased with the extensive student-student discourse that occurred during the PBL discussions.

The participants did not make many metacognitive statements that could help them solve the problem (6 out of 133). Prior research in mathematics has shown that reflective utterances during problem solving are rare compared to other types of talk, yet they are crucial to solving the problem efficiently (Schoenfeld, 1985). This is an area that the facilitator could concentrate on in future PBL classes. For example, most of Jenna's comments were answers about the PBL process (11 Tapro out of 15). She made three reflective comments about the problem (Tup). Still, at key points, perhaps more statements from the facilitator to help students evaluate the state of their understanding would have been helpful. For example, during Physics instruction, Jim Minstrell, an expert teacher, utilizes "reflective tosses" that catch "the meaning of the prior student utterance and 'throws' the responsibility for thinking back to the students" (van Zee & Minstrell, 1991, 1997a, 1997b). For teachers to insert reflective tosses effectively, they need some domain knowledge, at least. Science knowledge was not required for teaching assistants in the course because it was an Educational Psychology class, but it could be encouraged for the particular cases that teachers facilitate.

*2) Use of Resources*

Overall, throughout the course, the mentor turned out to be useful despite the fact that all interactions with the mentor were made through the facilitator. There is no evidence why this has happened, although when we asked Jenna about it, she clarified that she did it because she thought it was important to emphasize the importance of strong domain knowledge and she did not think they would do it themselves. Currently, the STEP team is working on technology to further support the PBL facilitators, including a way for them to discuss instruction amongst themselves; perhaps, it would also be helpful to create an online community for the disciplinary mentors to provide them further support.

Our facilitator felt it was her duty to contact the mentor on behalf of the preservice teachers in solving the domain specific problem that they had encountered. The role carried out by our facilitator was a "mediator" between students and mentors similar to a study conducted by Tsikalas and McMillan-Culp (2000). These authors argued that the role of the facilitator as community builder and mediator was a key factor in building effective relationships.

As teacher educators who were conducting the PBL course for the first time, we did not anticipate that the facilitators would need to be well versed in the domain knowledge of the video cases. Future facilitator training for this course will be enhanced to include domain knowledge tailored to the needs of the video cases.

In future projects, we will concentrate not only on the roles of the facilitator and mentor in sustaining a relationship, but also on the student teacher's responsibilities and communication skills. The National Academy of Science defines an effective student-mentor interaction as advancing "the educational and personal growth of the student" (NAS, 1997). Although the situation in our course was different because our students were undergraduate, preservice teachers and our science mentors were graduate students, we believe that the NAS recommendation pertains to our course in that student teachers can take on more proactive roles in the mentoring relationship. Certain studies have revealed that students are often in positions of greater control in telementoring relationships than mentors and need to be prepared as well (O'Neill, 1988; Tsikalas & McMillan-Culp, 2000).

The roles played by the participants in this analysis were unique and co-constructed by the participants. For example, Laura most frequently asked science questions, especially after a statement had been made about science. Dean on the other hand, attempted to answer most of the science questions. Lou was a collaborator, asking critical science questions and attempting to answer at various points. Cindy was the synthesizer in terms of clarifying, agreeing or disagreeing with statements made. Bo held a peripheral role in participating verbally in a limited way, but no less non-verbally. In Lemke's study (1990), on science classroom dialogue, he argues that patterns of relationships are social constructions as a result of history where individuals' actions recreate and change these patterns over periods of time. These patterns depend on the social role an individual represents. This statement sheds light on the roles the preservice teachers played in our study as well, because we did not assign the roles that were displayed in our video analysis but they were socially constructed.

In addition, two other resources were used. The textbook and physics professor were utilized proactively by the preservice teachers without guidance from the facilitator. We were pleased that they sought out these two resources. However, their dialogue about the value of these resources show that they did not think they were as informative as they had expected.

It was not a surprise to the authors that the preservice teachers sought the use of the World Wide Web for seeking information on the subject matter. The preservice teachers' use of the World Wide Web depicts an increased reliance on quick searches of online resources. However, we are concerned that none of the preservice teachers queried about the trustworthiness or challenged the information that Dean found on the web. This suggests to us that our course should provide more scaffolding about media literacy and Internet evaluation, especially searches for resources that are directly related to our course. However, we also predict that media literacy and all the varied related issues such as quality, accuracy, trustworthiness and evaluation of a Web site requires time and resources outside of this course.

Our study reveals ways to structure professional development activities to help teachers be lifelong learners. It has also been recommended that maintaining a network keeps teachers engaged and connected; these communities are organized to assist teachers who are often alone in their classrooms to share teaching materials and information about resources (Loucks-Horsley, S., Hewson, P.W., Love, N., & Stiles, K.E., 1998). We hope to conduct further research on ways teacher educators can support preservice teachers to successfully instantiate online inquiry. This includes the effective application of resources that will enhance the preservice teachers' subject matter knowledge and pedagogical content knowledge (Shulman, 1987). We are also looking into ways of preparing our facilitators to scaffold preservice teachers' discussions effectively.

*3) Preservice Teacher Learning*

Our claim is that the student teachers demonstrated thorough scientific reasoning during the video segment. Especially after science and science-education experts reported that the questions generated were rare and difficult to answer, this showed that the participants had delved deeply into the domain of physics and chemistry. Much previous research on students' understanding of electricity has shown that the domain is difficult (e.g., Eylon & Ganiel, 1990; Gutwill, Frederiksen, & White, 1999). Gutwill (1999) found that high school students were able to use simpler particle models, but not more sophisticated models of static electricity. In our study, we also found that the student teachers' struggle was not with using simpler models, but when they tried to explain whether the bonding behavior of the rod and fur change when they are charged. One of the experts we informally interviewed revealed that he had to use a quantum model ("with conduction bands etc.") in order to begin to answer this question, rather than a simple Bohr model, complex Bohr model, or energy model ("with bonding potentials and stability arguments about bonding") (Personal Communication). Further research on student teachers' conceptions of electricity, especially in relation to ways that they design instruction, would be an interesting next step for our project.

The discourse analysis also revealed that participants made conjectures, agreed and disagreed, and challenged each other's ideas. They engaged in a sense-making episode in that they struggled to explain static electricity on a deep level.

Finally, we found that the student teachers shifted the learning issues that arose during science inquiry to instructional questions. What they learned during the remaining PBL sessions were instructional approaches to the topic of static electricity. Through connecting their own intuitions with research, they decided that static electricity is not a suitable topic to teach, and instead proposed a focus on atomic models and charge separation. As the final paper shows (see Appendix 3), they were able to professionally present an instructional rationale for models, misconceptions, and model use.

**Instructional Implications**

In this section we describe three principles gleaned from this study to improve our own instruction that other educators might find helpful if adopting a similar instructional approach with preservice or inservice science teachers.

***Student teachers should take on a collaborative responsibility for scientific thinking.*** The conventions for discussion that a teacher constructs with her group are crucial for promoting collaborative discourse. Teachers (or students) should be responsible for making sense out of science for two reasons: (1) so that they learn it, and (2), so that they acquire the habit of collaborating as professionals. In the PBL course we taught, each student teacher was responsible not only for their own learning, but also the learning of each member of their PBL discussion group. Silence during discussions represented assent, and participants were expected to challenge each other's ideas.

***Facilitate reflective discourse.*** Discussion leaders should help students reflect on their ideas. We found that the student teachers needed further help in regulating their state of understanding. By facilitating reflective moments, a teacher can enable participants to clarify what they already know, what they need to know, and help them decide if it makes sense. Effective facilitation requires at least minimal domain knowledge, and likely, knowledge about common misconceptions and typical trajectories of development.

***Provide and guide the use of authentic resources for science learning.*** The resources provided in our course were instrumental in helping students gain new scientific understanding. We argued that having the facilitator guide interaction with the mentor, rather than interact herself, might be more useful for the student teachers. Part of what student teachers require for lifelong learning are the tools to further their knowledge. But they also need direct experience with using authentic resources - and a class structure that values these experiences.

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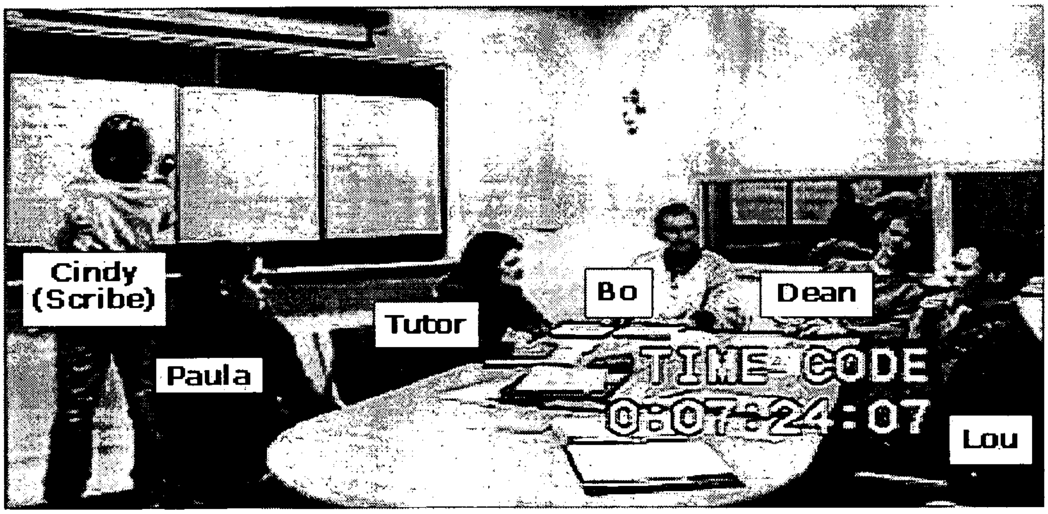
## Appendix 1: Coded Transcript
(n.b. codes are not final)




| Time, Speaker | DISCOURSE CODE | TRANSCRIPTION |
|---|---|---|
| (7:00) | | ((transcript begins)) |
| (7:00) DEAN: | | And I, don't mean, physical representations. |
| (7:03) PAULA: | Aa | Right, we °understa-°= |
| (7:04) DEAN: | As | =I mean as scientific models.<br>(.) |
| (7:07) PAULA: | Qch | Did he use those though? |
| (7:08) DEAN: | As | [Yes. (.) He used the Bohr model [of the atom]= |
| (7:08) BO: | Aa | [(Yeah xxxxx.) |
| (7:10) CINDY: | Aa | [The Bohr model.] |
| (7:11) DEAN: | As | =As well as um static electricity being based on the transfer of electrons. |
| (7:15) ?: | | Um hm. ((JENNA nodding)) |
| (7:15+)DEAN: | As | So he was basing- (.) (What it was) they were ↑observing, on some overall model of how, things behave so >that WAS A BONUS?< |
| (7:22) PUALA: | Aa | Okay. |
| (7:23) DEAN: | As | >Not that he DID it all that well< but,= |
| (7:24) (PAULA): | Aa | Um hm. |
| (7:25) DEAN: | | =it was it was THERE. ((emphasizes with palms up))<br>(1) |
| (7:27) JENNA: | (T) | ((to LOU)) You look like you ( ) |
| (7:29) LOU: | Qs | Ah no. Ah? (.) The one thing I was wondering when people do this is why is there things °xxxxxx°<br>>[I] don't know why.<= |
| (7:38) DEAN: | Aa | [Yeah.] |
| (7:39) LOU: | S | =I don't know why like cat hair and, plastic (1) work the best. |
| (7:43) DEAN: | Aa | Yeah I wonder that, myself (Lou). |
| (7:45) PAULA: | Ad | (I was) explained that once but don't ask me to repeat it. ((PAULA chuckles)) |
| (7:48) LOU: | Up | ((to JENNA)) So this has nothing to do with this so. ((LOU laughs)) |

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| (7:50) JENNA: | Tup | Oh I think it could? I think it could because it may have been a question, that the ↑students might have that (the students can) address. |
| (7:57) DEAN: | (Apro) | And I think that's something a little more complicated than a two day course is going to allow. BUT, (.) ((nodding)) yeah.<br>(1) |
| (8:04) JENNA: | Tapro | I- any idea is a good idea right now. = |
| (8:06) DEAN: | Aa | Yeah. |
| (8:06+)JENNA: | Tapro | =We're just brainstorming. (1) So (pose the risk) (3) ((CINDY whispering to PAULA)) |
| (8:12) CINDY: | Qs, Ad | °(I don't know isn't-)° ((to group)) Isn't there a rule like on the x table that talks about- I'm bi[ology so |
| (8:17) DEAN: | As | [No. (.) No. |
| (8:18) CINDY: | Qs | But >[DON'T metals always accept electrons?< |
| (8:18+)DEAN: | As | [Xx. (.) But that's for, that's for bonding. |
| (8:21) (PAULA): | Aa | (Um hm.) |
| (8:22) CINDY: | Aa | [Right. (.) Okay. (.) Okay. |
| (8:22) DEAN: | As | [This is just to transfer of electrons in terms of static electricity which is, not an actual chemical bond being formed but just the electrons are sh, changing locations. |
| (8:30) CINDY: | Aa | [Okay. (.) Okay. (1) Okay. |
| (8:30) DEAN: | As | [So it takes the electricity and [xxx. |
| (8:31) PAULA: | Qs | [Where are they coming from. |
| (8:31+)DEAN: | | Where are they coming from? |
| (8:32) PAULA: | S | That's the one thing about- they're not just floating around. |
| (8:35) DEAN: | As | [No they're not.] |
| (8:35) LOU: | (As) | [xxx.] (Like you use it enough and it's just like (.) ((brushes away air with his hands)) it's done. ((DEAN laughs)) |
| (8:40) PAULA: | Qs, Ad | But, aren't you going to be changing the chemical composition? (.) (But) I'm sorry. |
| (8:44) JENNA: | Tapro | ((waving pencil)) Well I think we have a cou[ple of- no:, no: I think this is good.= |
| (8:45) | | [((laughter from DEAN)) |
| (8:47) JENNA: | Tapro | = I think we have a couple of things, going on here, that we need to (help). That we need [to slow down and maybe EVEN if we can write down too, the learning issues.= |
| (8:50) CINDY: | | [((reaches for PAULA'S hand)) °(Wa:tch)° ((they both raise their hands and then laugh)) |
| (8:55) JENNA: | Tup | We need to:, ah, make sure that we get down, that, one possible thing we want to change is to explain, (.) ah why (.) different materials= |
| (9:04) LOU: | | Um. |
| (9:05) JENNA: | Tapro | =accept, (.) different kinds- ((to LOU)) You say it. |
| (9:08) LOU: | Up | Ah:::, why >I don't know.< Why different materials [accept or donate] electrons. |
| (9:12) DEAN: | Up | [x. Yeah,] (.) electrons. And ah: we also, wanted, (2) I think we need ta:, we need to explain more about, conductors versus insulators because he sort of talked about it, but for the thirty seconds he did, he then expected them to understand (.) exactly why charges would line up on, different sides of |

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| | | something and, that's not really intuitively obvious unless you REALLY understand what a conductor means. It means that electrons are free to, ((raises hands with palms downward)) float around the surface. |
| (9:43) JENNA: | Tup | So we need to handle insulators and conductors, (.) better. |
| (9:47) DEAN: | Aa | °Yeah, and,° ((he looks up in thought))<br>(1) |
| (9:50) JENNA: | | Well let's let- |
| (9:52) DEAN: | | [xxx.] |
| (9:52) JENNA: | Tapro | [Before we go] (1) further, write write down what you're thinking about. >And before we go further let's put down the learning issues because I think that's something there are things that we need to KNOW thayou're saying we don't know that we can ask our mentor.< So, what are those things so that she can write up our learning issues. ((to PAULA)) You were asking a question and I was thinking so I don't know what it was.= |
| (10:08) PAULA: | Qp | =I was asking a science question (is that okay?) |
| (10:10) JENNA: | Tapro | A science question is valuable if it pertains to this. If if it's something we think that they need to- that the kids might be wondering about too that. |
| (10:17) PAULA: | Qs | Where do the electrons come from that transfer.<br>(2) ((DEAN raises his hand and then puts it down and tightens his lips )) |
| (10:21) LOU: | Apro | You can answer it. |
| (10:22) JENNA: | Tapro | ↑Yeah you can answer [it.] |
| (10:23) DEAN: | Apro | [Oh.] I thought we were just writing down the learning issues. Ahm:? |
| (10:27) PAULA: | Qs | And why doesn't it change the chemical composition if you're taking electrons away and why (doesn't) it all of a sudden want to bond with something. |
| (10:33) LOU: | Ap | (Oh) I can answer that part. |
| (10:35) PAULA: | Up | [(There's two questions in there.)] |
| (10:35) DEAN: | Ap | [Well between Lou and I!]<br>(.) |
| (10:37) PAULA: | | : Hmph. |
| (10:38) CINDY: | Apro, Qp | WAIT. ((She is writing on the whiteboard)) (2) Okay. Should I write the answer up there too? |
| (10:43) JENNA: | Tapro | Let's write that under knowledge. ((turning around to look at the whiteboard)) |
| (10:45) CINDY: | Aa | Okay.= |
| (10:45+) DEAN: | | =Well.= |
| (10:46) JENNA: | | ((getting up to help CINDY)) =We need.= |
| (10:47) BO: | Qch | =Did you explain it right? Are you really just transferring electrons or are you just (moving them around?) |
| (10:51) DEAN: | As | You're [transferring electrons. |
| (10:51+) PAULA: | S | [You're transferring electrons. |
| (10:53) CINDY: | (A) | Some[times you xxxxxx.((she moves her hand back and forth in the air)) |
| (10:53+) DEAN: | (A) | [That's (how you don't xx-) |
| (10:56) LOU: | (A) | (I have a:) like on the conductor, on this little ball that was xxx= |
| (10:59) DEAN: | Aa | =Yeah.= |
| (11:00) CINDY: | (A) | =[They're only xxx (touch). |
| (11:00) LOU: | | [xxxxxxxx[xxxxx. |
| (11:01) DEAN: | As (S) | [And you're, well you're, (.) and well you're still transferring them from one side to the |

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| | | other. [So you may not be:,= |
| (11:04) CINDY: | Aa | [You're right okay. |
| (11:05) DEAN: | Ap | =(pretty obvious) |
| (11:06) PAULA: | As | Yeah but you're tra:nsfering electrons from the substance he's rubbing across [the, the thingamabob.]= |
| (11:08) DEAN: | Aa | [Yes. (2) That is true.] |
| (11:11) PAULA: | As | = The plastic or whatever he has, [(x to it.) ((demonstrating with hands)) |
| (11:12) DEAN: | As | [And you're taking electrons, from the cloth, ((clapping hand for emphasis)) [and transferring them, to the rod. |
| (11:16) PAULA: | Un | [Okay that's the part that I don't understand. |
| (11:17) DEAN: | Qc | What what, (.) what about it specifically cause you [take- |
| (11:20) PAULA: | Qs | [How, where are these electrons coming from. Say I'm putting taking electrons from here and putting it HERE? ((she points to one hand and then to the other)) |
| (11:26) DEAN: | Aa | Yep. |
| (11:26+) PAULA: | Qs | There's not just free floating electrons are there? |
| (11:29) BO: | As/S | °Well they're (groun[ded.)° |
| (11:30) DEAN: | As | [No but every[thing, everything- |
| (11:30+) PAULA: | S | [They're not just like all over the place. |
| (11:32) DEAN: | S, Ap | ((Hands on the back of head)) Everything is at a different potential? (1) Um:, and normally it's the earth ground potential. (1) But you're changing the potential of one thing and the potential of the other, (.) in the same way. ((motioning with hands)) (.) You know you're, you're increasing the voltage over- (.) ((Bo crosses his arms)) °well not voltage ah:.° ((waves away the comment with both hands)) Okay now how (can we) let me rephrase this to help you. Um::. ((He taps his fingers on the table)) (2) |
| (11:56) PAULA: | Qs | You're stripping it from what. From molecules? From atoms? |
| (11:59) DEAN: | As | From the mol- from the [↑molecules in the substance. ((emphasizing with hand)) |
| (12:00) PAULA: | S | [You're taking it from the atoms themselves.= |
| (12:01) DEAN: | As | =YES. You are tak[ing electrons. |
| (12:02) PAULA: | Qs | [And you're not, you're not going to make it want to bond more with something else? |
| (12:06) DEAN: | As | You will. (2) Because, if you change the elec- ((PAULA laughs, DEAN covers his face with his hands.)) |
| (12:12) CINDY: | | So it- |
| (12:13) DEAN: | | Um not- (1) hhh |
| (12:16) CINDY: | | (Or) you're not taking it= |
| (12:17) DEAN: | Ap | =I don't know how to explain this [in few sentences without taking, an hour. |
| (12:19) PAULA: | | [Wait. What I- |
| (12:21) PAULA: | Uh | uh. ((She climbs out of chair and goes to board and draws)) What I'm picturing is here's an atom and here's an [atom and here's all the electrons] (are swarming around) and all of a sudden I just took this |

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| | | one. |
| (12:24) DEAN: | Aa | [Yeah, ((nodding)) (.) I real- I realize what you're saying.] (.) |
| (12:29) PAULA: | Uh | And now, it's gonna, want to bond more with xxx ((sound is warped)) Let's take another one from that too. Now it's going to want to bond differently. |
| (12:36) DEAN: | As | Well not necessarily. Um::, (1) It's not necessarily going to make it bond with something that's around, but it will change it's behavior chemically. >But it's not necessarily going to up and bond with something just because you took an electron away.< (1) Um::. |
| (12:49) LOU: | As | It's going to lose the electrons, (1) but (1) I ↑think it will probably pick them up somewhere else. (.) |
| (12:55) PAULA: | Ad | So [the, the |
| (12:55+) LOU: | S | [I think that's what happens. I'm not sure about that but [it's not going to |
| (12:57) PAULA: | Qs | [So if I charge this thing, so where have the electrons gone on this thing. |
| (13:01) LOU: | As | ((demonstrating with his hands)) So you have your cat hair [and your stick. |
| (13:02) PAULA: | As | [So all of a sudden it's going onto the [stick. |
| (13:04) LOU: | As | [They go from onto the [stick, and then |
| (13:05) CINDY: | As | [They go back to the air and [then, |
| (13:06) PAULA: | As | [And then I have a whole bunch of these. ((continuing to diagram on the board)) (.) [xxxxx. |
| (13:08) LOU: | Aa | [Well they stay on the stick and I don't know where the cat hair picks up it's electrons. |
| (13:11) CINDY: | As | ((pointing to paper on table)) But (well) when the stick gets (into) here eventually this thing, this, (.) the stick puts them on here, but eventually this doesn't work anymore. |
| (13:18) LOU: | Aa | Yeah.= |
| (13:18+) DEAN: | Aa | =Yeah because they were, |
| (13:19) CINDY: | As | Because (they) went back to:= |
| (13:20) DEAN: | As | =Because they were dissipated,= |
| (13:21) CINDY: | Aa | ↑Yeah. |
| (13:21+) DEAN: | As | =into the air um, [as soon as, as soon as he takes the cat fur and puts it on the table,= |
| (13:23) CINDY: | | [(The ground other things) |
| (13:24) DEAN: | As | =It can pick up electrons from the table.= |
| (13:26) PAULA: | Uy | Yeah well that makes sense. |
| (13:29) DEAN: | As | =And so everything is going [to return eventually to the earth GROUND, again. |
| (13:31) PAULA: | Uy | [That makes sense. |
| (13:34) DEAN: | Qs | But(.)temporarily we can move electrons around, AND, you are changing the ele- the electro-chemical potential?= |
| (13:40) PAULA: | Aa | Um hm. |
| (13:41) DEAN: | As | =For that compound. |
| (13:41+) PAULA: | Aa | Um hm. |
| (13:42) DEAN: | As | And, you may or may not cause it to react to something by doing that, ((marking points off on fingers)) but it's going to depend what the substance is, what it's in the presence of, (2) (you know) a |

| | | |
|---|---|---|
| | | WHOLE bunch of other stuff but you can- you WILL change it's chemical behavior.= |
| (13:53) PAULA: | Qs | =So why is it going to do that. ((raising arms to head and then dropping them to sides)) |
| (13:55) DEAN: | Qc | [What. |
| (13:55) LOU: | Uh | [(If it, if it) it's really not, hanging onto these electrons, very hard= |
| (13:58) DEAN: | Aa | Yeah. |
| (13:58+) LOU: | As | =cause it doesn't want them that much. Otherwise it wouldn't (give up to this) pelastic stick. |
| (14:02) PAULA: | Qc | Okay [so? |
| (14:03) LOU: | As | [So, because it loses these really (.) ((brushes with hand)) light ones, it's not going to bond to anything really. |
| (14:08) PAULA: | | [(It's) |
| (14:08) LOU: | S, Un | [If you, were able to pull off, to pull them off. °I don't know how you would be able to do that.° |
| (14:12) DEAN: | As | The core electron.<br>(.) |
| (14:13) LOU: | | Then it would be really [xxxx= |
| (14:14) BO: | | [(So you're losing) |
| (14:15) CINDY: | As | You're [losing the ones outside. |
| (14:16) LOU: | As | =[The stick's not going to pull [those off. |
| (14:17) BO: | Aa | [°Yeah.° |
| (14:18) PAULA: | Aa | Okay.<br>(2) |
| (14:20) DEAN: | As | And you, [you are increasing it's reactivity. |
| (14:20+) PAULA: | | : [(I I) |
| (14:23) PAULA: | Aa | Okay. |
| (14:23+) DEAN: | As | I would bet. But not to an extent where it's going to blow up on you. |
| (14:27) PAULA: | As | So it doesn't care really either way but it's kind of like well if they're there.<br>(.) |
| (14:31) LOU: | Aa | [Yeah. |
| (14:31) PAULA: | As | [When when you ground it. ((hands on table)) Well if they're there I guess I can (hand them back [again) |
| (14:34) DEAN: | Aa | [Yeah. |
| (14:35) LOU: | Aa | Yeah.= |
| (14:35+) PAULA: | (a) | =But otherwise it's like whatever (else) ((she laughs and looks at JENNA who smiles)) |
| (14:36) DEAN: | Up, Ad | And this (gives you new) insulator versus conductor issues because, when you have a metal, (.) um: (1) well no metals, will readily transfer their electrons around which is why they make good conductors. Um the, energy °ah, I'm getting this (confused x).° |
| (14:54) JENNA: | Tapro | Well okay let's let's let's (turn) it off for here right now but let's think about this more because I think this is good because you do need to think about the things, that are important for him to tea:ch and, how, we think he needs to teach them. |
| (15:06) PAULA: | Aa | Uh hm. |
| (15:06+) JENNA: | Tapro | And these are all, (.) >the the< domain knowledge is incredibly important, to, (.) to (teaching). So, I [found this, very valuable.<br>((PAULA smiles at camera)) |
| (15:13) DEAN: | Qp | [So, so what IF, for next time (3) I'll split this up with Lou since he seems to be the other person who,<br>(.) |
| (15:23) JENNA: | Tqc | Well? |

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| | | |
|---|---|---|
| (15:24) DEAN: | | [And we- |
| (15:24) JENNA: | | [We can we can make it a learning issue something that we need [to write about.= |
| (15:26) DEAN: | | [Okay. |
| (15:27) JENNA: | | =↑So, where do electrons come from<br>(1) ((CINDY writes on whiteboard)) |
| (15:30) DEAN: | | Well how does conduction and, how >does (it all)< work anyhow.<br>(.) |
| (15:33) JENNA: | | What? |
| (15:33+) DEAN: | | I mean how does THIS, (.)((waving hands at papers on table)) all work anyhow, is I think the question we could ask. ((JENNA nodding)) And you can quote me on that.<br>(3) |
| (15:43) BO: | | [xxxx |
| (15:43) PAULA: | | [(I guess) how does static electricity work °(I guess)°<br>((PAULA, LOU, BO, and then DEAN all look at the camera)) |
| (15:45) DEAN: | | Oh you don't like my, ambiguous (slang)?<br>(3) ((BO chuckles)) |
| (15:51) DEAN: | | I was priding myself on that.<br>(.) |
| (15:53) CINDY: | | OKAY I HAVE A THING. (1) °Where did it go° to change. |

# Appendix 2

Transcription Conventions

| | | |
|---|---|---|
| Timing | | |
| Brackets | [ ] | Marks the beginning and end of temporal overlap among utterances produced by two or more speakers |
| Equal sign | = | Indicates the end or beginning of two sequential "latched" utterances that continue without an intervening gap. Where necessary, the symbol can be used in combination with brackets. |
| Timed pause | (1.5) | Measured in seconds, this symbol represents intervals of silence occurring within (i.e. pauses) and between (i.e. gaps) speakers' utterances. |
| Micropause | (.) | A timed pause of less than 1 second. |
| Delivery | | |
| Comma | , | Indicates a continuing intonation with slight upward or downward contour that may or may not occur at the end of a turn constructional unit (TCU) as in the enunciation of an item in a not yet completed list. |
| Period | . | Indicates a falling pitch or intonation contour at the conclusion of a TCU. |
| Question mark | ? | Rising vocal pitch or intonational contour at the conclusion of a TCU. |
| Exclamation point | ! | Marks the conclusion of a TCU delivered with emphatic and animated tone. |
| Hyphen | - | An abrupt (glottal) halt occurring within or at the conclusion of a TCU. |
| Colon(s) | : | Indicates sustained enunciation of a syllable vowel or consonant. Longer enunciation is marked using two or more colons. |
| Greater than/ less than signs | >< <> | Portions of an utterance delivered at a noticeably quicker (> <) or slower (< >) pace than the surrounding talk. |
| Capitalization | | Represents speech delivered more loudly than surrounding talk or an emphasized word or sound. |
| Underscored text | | Underscoring indicates stress on a word, syllable or sound. |
| Arrows | ↓↑ | Marks a rise or fall in intonation |
| Other | | |
| | hhh | Audible expulsion of breath (linguistic aspiration) as in laughter, sighing, etc. When aspiration occurs within a word, it is set off with parentheses. |
| | •hh | Audible inhalation is marked with a preceding dot. |
| Parentheses | (  ) | Text enclosed in parentheses represents transcribed talk for which doubt exists. Empty parentheses represent untranscribed talk or unknown speaker. |
| Double parentheses | (( )) | Transcript annotations (text italicized). |

# Appendix 3
# Excerpt from Final Paper

Static Electricity: Misconceptions

The term *static electricity* is scary. It is not only scary for students who have to decode confusing concepts and language, but also for educators attempting to deal with student understandings that are based largely on misconceptions. Students' alternate conceptions are common to all areas of science and are based upon prior instruction and prior life experiences that students have had. This is especially prevalent with the topic of static electricity. Not only is static electricity a relatively intangible topic for students, but also the language used by textbooks is often confusing and helps to promote these misconceptions (Beatty, http://www.eskimo.com/~billb/emotor/stmiscon.html).

Before teachers can confront student alternate conceptions, they must define the term *static electricity*. *Static electricity* refers to a collection of phenomena in which the amounts of positive and negative electric charge within a material are not equal. Electric fields (as opposed to magnetic fields) become very important and electrical forces (attraction and repulsion) are seen to reach across space

(Beaty, http://www.eskimo.com/~billb/emotor/stmiscon.html).

Teachers must confront several common misconceptions in order for students to have a better model for understanding static electricity, several of which originate with the label *static electricity*. First, the term electricity applies to such a wide array of topics that its use is confusing. It could refer to "quantities of electrons or quantities of electrical energy. ...Or quantity of potential, or forces, fields, net charge, current, power, or even about classes of electrical phenomena" (Beatty, http://www.eskimo.com/~billb/emotor/stmiscon.html). In order to prevent student misunderstandings and confusion, teachers must use specific language. In addition, static electricity is not electricity, which is static. "The motion or 'staticness' of the charges is irrelevant. Separated or unbalanced charges can sometimes flow along. It is possible to create flows of so-called "static" electricity" (Beatty, http://www.eskimo.com/~billb/emotor/stmiscon.html). Instead, of using the term *static electricity*, it would be more correct to discuss *charge separation* (Beatty, http://www.eskimo.com/~billb/emotor/stmiscon.html). Beatty compares our mislabeling of electricity into two kinds, static and current, to teaching students that there are two kinds of water, static water and water that flows. In these ways, the very label of static electricity breeds misunderstandings.

In addition to the general misnaming of these phenomena as static electricity, several other common alternate conceptions exist. Due to the ways in which static electricity phenomena are often demonstrated, it is a common belief that friction is necessary for charge to become unbalanced. Although friction can often facilitate charge storage, charges can become unbalanced between two objects without any friction. Second, static electricity is often discussed in terms of a buildup of electrons, when the transfer of electrons is creating both negatively and positively charged regions. This imbalance of charge is the important phenomena, not the movement of electrons. This is especially relevant to batteries or capacitors, objects that store charge. Batteries are not filled with charge. In fact, an empty battery has the same charge as a *charged* battery. Batteries are not charged with electricity, but rather with energy. It would probably be better to abandon this use of the word charge, as it is a contradiction. Third, objects are labeled as either charged or neutral, when all matter consists of positive and negative charged particles, which is often ignored (Beatty, http://www.eskimo.com/~billb/emotor/stmiscon.html). These are just some misconceptions that exist concerning static electricity. It is important that any instruction includes a discussion of these misconceptions.

Model of the Atom: Misconceptions

Teachers need to be aware of misconceptions so that they are not perpetuating new ones through their instruction. To assist students in understanding the structure of atoms, teachers generally use a number of different models to represent characteristics of an atom. "Many students however, find the diversity of models used to represent specific phenomena both challenging and confusing" (Harrison and Treagust). Instructors must be aware of the limitations of the various models, and point them out the to students so that incorrect information presented by the models is not assumed to be true. The following are four of the

most common type of models used by chemistry teachers in describing the atom: Scale models (or space filling) Ball and Stick models, Lewis structures, and Structural formula models. All of these models portray some characteristics of atoms correctly, such as bond angles and valence electrons. Nevertheless, all also misrepresent some characteristics of the atom. Teachers must be consistent in filtering out incorrect information. In addition to these difficulties, both students and teachers encounter the problem of applying atomic theory to an environment outside of the school setting. "Scientific models of an atom as typically taught can appear to be abstract, and hardly, if at all relatable to everyday experience" (Griffit and Preston).

Student misconceptions about the atom are not limited to those students who are weak in science. Griffit and Preston's study, found both *science* and *non-science* students had about the same number of misconceptions. Consequently, even teachers who teach advanced level science courses need to be aware of students' prior experience and tailor their lesson plans accordingly. Griffit and Preston found that usually the misconceptions of science students arose out of prior instruction of the subject. Griffit and Preston's study was conducted in Australia using both science and non-science high school seniors. *Science* seniors were students who considered themselves good at science classes. One common misconception about atoms found in this study is that the nucleus of an atom contains the information necessary for the atom to replicate. Students are confusing the cell versus the atom, leading them to believe that because the two share a common name they also share common characteristics. This is one example of students forming a misconception about a concept because of the instruction. Also potentially confusing are teachers' uses of metaphors in describing characteristics of atoms. Commonly the environment of the electron is called the *electron shell* or *electron cloud*. When students were asked the meanings of these words, students responded that the "electron cloud protects the nucleus" and that the "electron cloud is a soft covering over a harder nucleus" (Griffit and Preston, p518).

Using Models: How to evaluate and Change Them

In light of these misconceptions, instruction needs to focus on the relevant scientific models, which will provide students with a conceptual for creating correct understandings of the phenomena associated with static electricity. The two most important models that students will need to understand these phenomena are the model of the atom, Quantum Mechanical Model or Bohr Model, and a model of electrical charge. Due to the time constraint, instruction should focus on developing students' understanding of electrical charge and how it relates to their pre-existing model of the atom (S. Peterson, personal communication, April 6, 2000).

As mentioned earlier, instruction should focus on challenging the alternate conceptions that students possess. When students have constructed a new model for how static electricity phenomena occur, it is important for students to learn how to judge the value of that model. All scientific models are evaluated on three criteria: (1) how well does it explain the data? (2) How consistent is it with scientists' current understandings of the world? (3) How well does it predict future outcomes? If students learn what constitutes an acceptable model they will be better equipped to deal with their own alternate conceptions as well as future models they come across.

## Appendix 4: Interactions with Mentor

**Thursday, March 30, 2000 5:35:30 PM**
**Subject:Hello Mentor!**
**To: Science-Jenna**

Hello Mentor!!

The problem solution is on the way. I am the tutor for this group and I wanted to ask you a few things.

1. Could you please post a message introducing yourself and describing how you see your role in helping our group.

2. Our group has proposed that static electricity is probably not a central concept that students' need to understand. They are currently discussing ways to try using a model of the atom as the central concept and use static electricity to illustrate it.

Do you agree/disagree with their opinion that static electricity is not a central concept that kids will likely transfer to other contexts beyond this lesson?

3. Finally-- Thank you for being our mentor! There has already been a lot of domain-specific discussion in our group that have generated a lot of interesting information and puzzling questions. One big question is what knowledge should we teach and why--what will students use it for? What do you think students need to know about static electicity, if anything?

Jenna Seymour

**Thursday, April 6, 2000 5:17:22 PM**
**From: Breno**
**Subject: Re: Hello Mentor!**
**To: Science-Jenna**

First of all, I want to apologize for the lateness of this message. I hope that it is still of some use to you.

I do agree that static electricity is not the central issue here. Static electricity should not be the headline topic. It is a fun application of charges and electicity; one that everyone knows something about. Static electricity can be an introduction, but it is not a concept.

As for what concepts should be covered/discussed, I agree that a model of the atom is very important and plays well here in regards to topics like chemistry and the like. But if this discussion is to preface other Physics topics, I think that the core concept is electric charge. Electric charge is the basic unit of voltage and current; it also leads quite well into electric and magnetic fields. So, it sounds like in this particular classroom, these topics were not going to be discussed, so I would think the atom would be more important. I guess that this is an issue that you can discuss.

Lastly, I am not saying that electric charge and the model of the atom are not related and can't both be used. I think that we all realize that these charges are just the electrons jumping from atom to atom, so there is a strong relationship. But from my own experience, if there are bigger electrical topics following in the rest of the course, like electric fields, then a strong knowledge of electric charge is essential.

I hope that this has helped. If you have any more questions, please let me know. I want to remind you that my experience is strictly at the college level and may vary from the

high school level. I wish you luck on this project. I am also excited to know that there are people out there excited about teaching and sciences, especially Physics. Later, Breno

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